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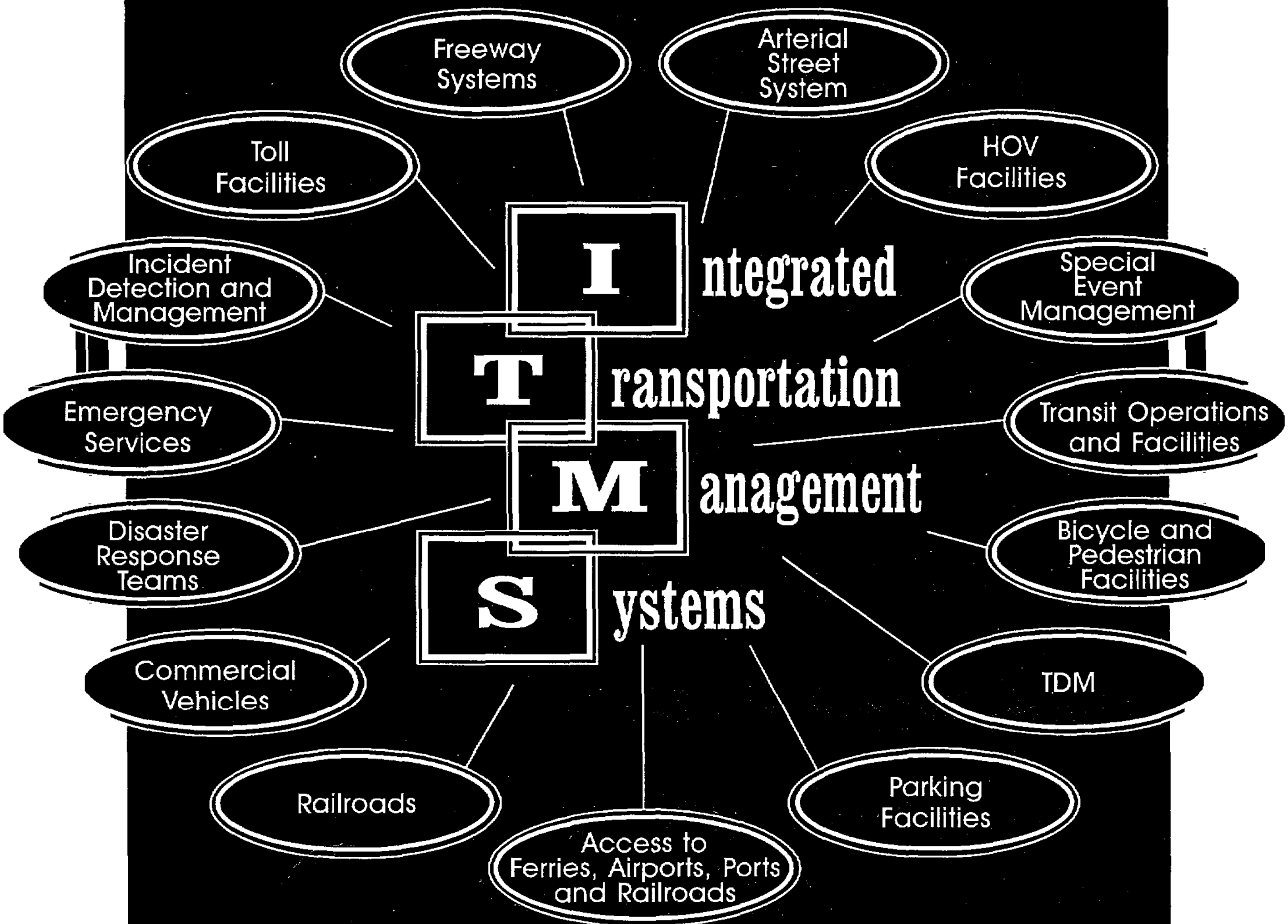
2nd National Symposium on Integrated Transportation Management Systems



May 8-10, 1995

Crowne Plaza Seattle Hotel

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SECOND NATIONAL SYMPOSIUM ON INTEGRATED TRANSPORTATION MANAGEMENT SYSTEMS

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Second National Symposium on Integrated Transportation Management Systems

May 8-10, 1995
Crown Plaza Seattle Hotel
Seattle, Washington

Presented by
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National Research Council

In cooperation with the
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Washington State Department of Transportation
City of Seattle
King County Metro
City of Bellevne

Symposium Proceedings

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FOREWORD

These proceedings summarize the highlights from the ***Second National Symposium on Zntegrated Transportation Management Systems.*** The Symposium was held on May 8 through May 10, 1995, at the Crowne Plaza Hotel in Seattle, Washington. The Symposium brought together individuals from throughout the country to discuss the status of Integrated Transportation Management Systems (ITMS), to identify the issues and opportunities associated with the deployment of ITMS, and to develop action steps to accelerate the advancement of ITMS.

The Symposium was sponsored by the Transportation Research Board (TRB) of the National Research Council in cooperation with the Federal Highway Administration, the Washington State Department of Transportation, the City of Seattle, King County Metro, and the City of Bellevue. It was co-sponsored by the Institute of Transportation Engineers Intelligent Transportation Systems (ITS) Council and various ***ITS America Committees.***

The Symposium opened with the presentation of seven resource papers defining the key elements of ITMS. The benefits of ITMS, selected case studies, and major issues were discussed at other general sessions. The 194 participants then spent a half-day in workshop sessions discussing the critical issues and opportunities relating to ITMS deployment and developing an action plan for future activities.

The issues identified in the workshops were ranked by all participants at the closing session. The listing of priority issues and activities will be used by TRB, ***ITS America***, the U.S. Department of Transportation, and other organizations to help ensure that ITMS is developed and operated to maximize the benefits to all groups. The results will also be used in planning other conferences, including TRB's ***Third National ITMS Symposium*** to be held in Boston in June of 1996.

A number of people contributed to the success of the Symposium and deserve recognition. First, I would like to thank the other members of the Symposium Planning Committee for the time and effort they put into organizing and leading different parts of the Symposium. Second, the authors of the resource papers and the speakers did an excellent job of summarizing the key elements of ITMS. Third, the moderators and recorders provided valuable assistance in facilitating the workshop sessions. Fourth, the TRB staff-especially Rich Cunard, Catha Stewart, Angelia Summons, Reggie Gillum, and Anita Brown-did an outstanding job handling the logistics for the Symposium. Finally, I would like to thank all of the participants for sharing their concerns, ideas, and visions related to ITMS.

These proceedings are intended to help facilitate the development of a strategic agenda to assist in the successful deployment of ITMS. I hope these proceedings will be of help to all groups involved with planning, designing, funding, and operating ITMS. Your involvement in future activities will be critical to advancing ITMS to help address the major transportation problems facing metropolitan areas today.

Leslie N. Jacobson
Planning Committee Chair

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SYMPOSIUM OVERVIEW

Leslie N. Jacobson, Washington State Department of Transportation
Katherine F. Turnbull, Texas Transportation Institute

The Second National Symposium on Integrated Transportation Management Systems was held in Seattle, Washington on May 8 through 10, 1995. The Symposium was sponsored by the Transportation Research Board (TRB) of the National Research Council in cooperation with the Federal Highway Administration, the Washington State Department of Transportation, the City of Seattle, King County Metro, and the City of Bellevue. It was co-sponsored by the Institute of Transportation Engineers Intelligent Transportation Systems (ITS) Council and ***various ITS America Committees.***

The intent of the Symposium was to review the current status of Integrated Transportation Management Systems (ITMS) and to discuss the issues and operational opportunities associated with the deployment of ITMS. Specific actions were then identified by Symposium participants to help facilitate planning, designing, and operating ITMS. The results of the Symposium, as summarized in these proceedings, provide the basis for a dynamic ongoing research and development program focused on advancing the effective and efficient deployment and operation of ITMS.

The Symposium brought together representatives from public and private sector groups involved in ITMS. Individuals from federal, state, and local governments, consulting firms, system suppliers, metropolitan planning organizations (MPOs), transit agencies, universities and research institutes, and other groups all participated. The Symposium opened with the presentation of seven resource papers defining the key elements of ITMS. The resource papers **and** authors were:

Integrated Transportation Management Systems: Definition of the Concept-Thomas Urbanik II
Integrated Transportation Management Systems: Environmental Considerations and Issues-Sarah J. Siwek
Multimodal ITMS: From Integrated Traffic Management to Integrated Transportation Management-Katherine F. Tumbull
Integrated Transportation Management Systems: Identifying the Disciplines that Make it Work-Douglas W. Wiersig
TRANSCOM's Development in New York, New Jersey and Connecticut: Multi-Jurisdictional Issues in ITMS-Matt Edelman
System Engineering: A Short Course in the Obvious-Tip Franklin
An ITMS Architecture Considered-Jim Kerr and Greg Mosley

Speakers at the general sessions also addressed the benefits of ITMS and presented information on selected case studies from throughout the country. The Symposium participants spent a half-day in workshop sessions discussing the critical issues and opportunities relating to ITMS deployment and developing action plans for future activities.

A wide range of issues, opportunities, and actions were discussed in the workshops. These were presented in the final general session, and participants were asked to rank the issues they felt should be given top priority. The following six issues and actions were rated highest by the Symposium participants.

Issue-The current methods of contractor selection and contract award are often inappropriate for procuring advanced technologies and related services.

Action

- Efforts are needed to explore alternative contracting methods to identify changes in legislation that may be needed to allow public agencies to use these procedures, and to document the experience with alternative approaches. Additional research, including the preparation of a Synthesis, best practice examples, case studies, and model guidelines and contracting procedures would be appropriate.

Issue-Performance guidelines for ITMS operations and maintenance are needed.

Action

- The development of performance guidelines for ITMS operations and maintenance should be pursued. These guidelines should consider a range of site-specific conditions, as well as identifying the expectations and roles of different agencies and groups.

Issue-There is a need to incorporate operations and maintenance considerations into the ITMS design process.

Action

- The development of best practice examples highlighting the inclusion of operations and maintenance consideration into the ITMS design process should be encouraged, as should support for the ongoing sharing of information. Possible approaches for consideration include the development of a Synthesis, best practice case studies, papers and presentations at future conferences, and the development of general guidelines for incorporating operations and maintenance consideration into the ITMS design process.

Issue-Explore funding support for ITMS.

Action

- Efforts should be supported to examine and identify innovative funding sources and approaches, to develop best practice case studies and reports documenting different ITMS funding techniques, and to continue to highlight examples at future conferences.

Issue-Identify the benefits of system integration.

Action

- Efforts should be supported to document the benefits of system integration, **to** identify alternative approaches, to monitor best practice case studies, and to develop general guidelines for system integration.

Issue-There is a need to better communicate the benefits of ITMS at the local level.

Action

- The development of information on the benefits of ITMS for use with local elected officials, the public, and other groups should be supported. Encouraging the ongoing communication among all groups at the local level should be part of this effort.

The other 14 issues are summarized next to provide an indication of the scope of the topics discussed in the workshop sessions. These issues can be explored in more detail at future conferences. The following list is not provided in any lcmd of priority order.

- Policy and legal guidance is needed to better defme what information is in the public domain, what information can and should be collected, and what information can and should be released to the media and other groups.

- There is a need to identify approaches to determine the value of the public resources and infrastructure used in ITMS, and to determine how ITMS-generated revenues can be used to operate, maintain, and expand ITMS.

- There is a need to clarify potential liability issues related to ITMS implementation and operation, and to determine how this liability can be allocated among the public and private groups involved in ITMS.

- There is a need to better define the concept of system integration in ITMS and its various components.

- There is a need to identify the benefits from system integration in ITMS .

- There is a need to examine the use of life-cycle costing with ITMS operations and maintenance programs.

- There is a need to determine how ITMS life-cycle costs can be minimized.

- There is a need to examine how ITMS guidelines and standards can be developed that address the rapid advancement or rate of change of technology.

- There is a need to explore policy and legislative changes that would provide greater opportunities and authority for partnering at both the state and federal level.

- There is a need to examine approaches that can be used to establish inter-jurisdictional teams in areas throughout the country needed to advance ITMS.

- There is a need to assess the future ITMS staffing requirements.

- There is a need to define the role and authority of metropolitan planning organizations (MPOs) in ITMS.

- There is a need to identify approaches for enhancing the involvement of transit agencies and operators in ITMS to ensure that transit is a full player in ITMS.

- There is a need to provide enhanced federal guidance on ITMS and other ITS programs.

These issues and actions will help facilitate de development of a strategic agenda to assist in the successful deployment of ITMS. They should be of benefit and of use to TRB, ***ITS America,*** FHWA, FTA, ITE, state departments of transportation, transit agencies, and other groups involved with planning, designing, funding, and operating ITMS.

OPENING SESSION-What Are Integrated Transportation Management Systems?

Thomas Urbanik II, Texas Transportation Institute-Presiding

Symposium Welcome

Leslie N. Jacobson, Washington State Department of Transportation

I would like to welcome you to Seattle and the ***Second National Symposium on Integrated Transportation Management Systems.*** The Symposium is sponsored by the Transportation Research Board, in cooperation with a number of other groups and organizations. Local sponsors include the Washington State Department of Transportation, the City of Seattle, King County Metro, and the City of Bellevue.

The opening session this afternoon is intended to set the tone for the Symposium. As the speakers at the Symposium will highlight, Integrated Transportation Management Systems, or ITMS, concerns more than just incorporating freeways and arterial streets into a coherent management system. A truly integrated system must also include other modes and functions. These may include transit, law enforcement, emergency services, information, planning, and many other applications.

ITMS represents a single system that is multimodal, multi-disciplinary, and multi-jurisdictional. Although establishing communication links among the different modes and agencies is a critical element, ITMS goes beyond this. It also encompasses how the information will be used and what actions will be taken to address specific issues.

Seven resource papers were written for the Symposium. These resource papers help define the ITMS concept and the various components of an integrated system. The papers also address many of the key issues and opportunities that may be encountered in planning, implementing, and operating ITMS.

The opening session will be followed this afternoon by another plenary session describing the benefits of ITMS in three areas-the Minneapolis-St. Paul metropolitan area in Minnesota; Montgomery County, Maryland: and Dallas, Texas. Three more case studies will be presented Tuesday morning. This session will highlight the experiences from Monroe County, New York: San Antonio, Texas; and Seattle, Washington.

The second session on Tuesday morning will examine four key issue areas that are critical to the deployment of ITMS. The areas to be addressed are roles and responsibilities, legal and procurement, systemintegration, and operations and maintenance. That session will help establish the focus for the workshop sessions on Tuesday afternoon, which will be oriented around the four issue areas.

The workshops represent a significant part of the Symposium and will provide you with the opportunity to discuss the issues and the opportunities associated with ITMS in more detail. More importantly, you will have a chance to help identify solutions to these concerns, establish priorities for further action, and outline other needs and opportunities with ITMS.

The results from the workshops will be presented at the general session on Wednesday morning. Each of the workshop leaders will summarize the main points discussed in the Tuesday afternoon sessions, and the top five issues will be identified. You will then have the opportunity to rank or prioritize the major issues from all the workshops.

The outcome of the Symposium, which will be published by TRB, will be used in a number of ways. First, the issues and actions steps will be provided to TRB, the U.S. Department of Transportation and the different modal agencies, ***ITS America,*** and other national organizations. They will also provide important input for the Advance Transportation Management Systems (ATMS) conference to be held in St. Petersburg, Florida this October. The results will further be utilized in planning for the Third TRB ITMS Symposium, which will be held in Boston in June of 1996. Finally, the results will be of benefit to you and others responsible for planning, implementing, and operating ITMS.

Your participation in the workshops and the Symposium is critical. It is only through your involvement that we will be able to identify the key issues and opportunities with ITMS. I encourage you to share your ideas and experiences with others. The Symposium will only be a success with your participation. I am looking forward to an interesting and productive two days.

ITMS: Definition of the Concept

Thomas Urbanik II, Texas Transportation Institute

I would like to start by introducing the members of the Symposium Planning Committee. Les Jacobson served as the Chair of the Committee. In addition to myself, the other members included Donald Dey, Frank Dolan, Raj Ghaman, Jeff Lindley, Jonathan McDade, Joseph McDermott, and James Robinson. These individuals put a great deal of time and effort over the past year into planning the Symposium. I hope you will find the next two days to be stimulating, challenging, and thought provoking.

As Les noted, seven resource papers were prepared for the conference and provided to you in advance. We have six of the seven authors with us this afternoon. They are Tip Franklin, Matt Edelman, Katherine Turnbull, Sarah Siwek, Jim Kerr, and myself. Douglas Wiersig was not able to attend due to a conflict.

Rather than asking each of the authors to present their papers, we have asked two outside experts-G. Scott Rutherford from the University of Washington, and Leslie Kelman from the Municipality of Metropolitan Toronto (Metro Toronto)-to summarize the highlights from the papers. We will then provide the opportunity for you to ask questions of the authors and for them to raise any additional points. We hope this interaction will continue throughout the Symposium.

As a way of establishing a common ground for the Symposium, I would like to start by defining ITMS and summarizing a few highlights from my resource paper. Although we often use the word systems, the focus of this Symposium and ITMS is on a single transportation system. This point is reinforced in all the resource papers, especially the two addressing system engineering and system architecture.

The benefits of ITMS will be described in the second session today. Selected ITMS case studies will be presented tomorrow morning, followed by presentations on the major issues associated with deploying ITMS. These plenary sessions will set the stage for the workshops which will help develop a strategic agenda to advance ITMS.

You may have noticed that there has been an important change from a traffic orientation to a transportation orientation with ITMS. This reflects a move beyond just coordinating the freeway and arterial street systems. ITMS is really focusing on the fundamental aspects of the transportation system; the movement of people and goods. With the addition of Intelligent Transportation Systems (ITS), the flow of information-which affects the movement of people and goods-is now an important part of the basic function of the transportation system.

Interrelated with this change is the movement from a traditional control philosophy to a management philosophy. In the past, the focus often was on controlling the signal systems, ramp meters, and other elements of the transportation system. More emphasis is now being placed on management of all elements of the system. This new approach focuses on the primary objective of ensuring an effective and an efficient transportation system. Effectiveness relates to doing the right things. This might include encouraging commuters to carp001 when possible or to leave earlier or later to maximize the effectiveness of the system. Once the proper balance is achieved, the efficiency of the system can be maximized.

A number of underlying issues related to the urban transportation system may cause problems in the deployment of ITMS and the effective and efficient operation of the transportation system. First, specialization can lead to problems. For example, many areas have city, county, and state departments of transportation, as well as multiple agencies responsible for transit, police, traffic, and other services. Each of these agencies have their own missions. Further specialization usually exists within each of these agencies. Traditionally, we have looked at planning, design, and operations as separate disciplines. In reality, however, all of these functions are interrelated. For example, an understanding of operational issues is critical to ensure good planning .

This fragmented approach worked well before we began to experience significant demands on the transportation system. The inability to expand the system in many areas has resulted in the need to better manage existing resources and facilities, however. ITMS and other tools and techniques will be critical to enhancing the overall management of the different elements of the transportation system.

It is also important to remember that ITMS is a process, not a solution. ITMS is not the answer. Rather, it is a process to help ensure a more efficient transportation system. ITMS includes enhanced monitoring of the system, using the resulting information to evaluate various alternatives, prioritizing the options, and selecting and implementing the best approaches. The process does not end here, however. An ongoing effort is needed to continue to monitor, fme tune, and evaluate all components of the system.

There are a number of tools and techniques that will need to be used as part of ITMS. These include transportation systems management (TSM) , congestion pricing, the various management systems, travel demand management (TDM), transportation control measures (TCMs), and ITS. Like ITMS, none of these are the ultimate solution. Rather, each approach can be used to help address the issues facing metropolitan areas throughout the country.

It is also important to realize that a number of institutional considerations may need to be examined in implementing and operating ITMS. Developing working relationships among the various agencies and groups responsible for ITMS will be critical. A number of good approaches have been used in different areas to facilitate multi-agency, multi-jurisdiction, and multi-disciplinary efforts.

At the federal level, there is an effort underway to develop a national ITS system architecture. This will assist in bringing all the various components used by different agencies together into a compatible system. The national architecture will help specify the interrelationships and interfaces among the various components. This does not mean that we will have total standardization. Rather, it will help ensure that information can be exchanged among numerous agencies and groups.

In conclusion, the deployment of ITMS will continue to evolve. This Symposium is part of that process. The results from the Symposium will assist in the ongoing development and deployment of ITMS. Your participation over the next two days will be critical to helping advance the state-of-the-practice and state-of-the-art related to ITMS. Thank you.

Resource Papers-Environmental and Multimodal Issues

G. Scott Rutherford, University of Washington

It is a pleasure, but also a challenge, to summarize resource papers prepared by other authors. The task was made easier, however, by the excellent quality of the papers prepared for the Symposium. I was asked to review two of the resource papers. The first, ITMS ***Environmental Considerations and Issues***, was prepared by Sarah Siwek of Sarah Siwek and Associates. The second paper, ***Multimodal ITMS: From Integrated Traffic Management to integrated Transportation Management,*** was written by Katherine Tumbull of the Texas Transportation Institute.

Leslie and I were given a further challenge to integrate the concepts presented in two other resource papers into our presentation. These papers were ***Systems Engineering-A Short Course in the Obvious*** by Tip Franklin of TRW, Inc., and ***An ITMS Architecture Considered*** by Jim Kerr and Greg Mosley of NET Corporation.

I will review the major points of the first two papers and then summarize a few common themes and issues, including those from other papers. To accomplish this, I will address the main points of each paper.

Sarah Siwek's paper starts out appropriately with a categorization of the problems facing the transportation system today. These include the growth in nearly everything-population, vehicles, households, vehicle miles of travel (VMT)_except transportation services. She also points out the well known fact that even if the necessary funding was available, it would be very difficult to build additional transportation facilities due to social, environmental, and other concerns.

The paper notes that the ITS automated highway system will not be a reality for a number of years. Other parts of ITS, such as driver information systems, do show promise of an early integration into ITMS, however. All these factors lead to the conclusion that we must find better ways to manage, maintain, and operate the current transportation system. Hence, ITMS becomes a critical component in maintaining an adequate transportation system.

The paper addresses the environmental issues related to developing and implementing ITMS. To accomplish this, a broad view of environmental issues is considered. As a result of the Clean Air Act Amendments of 1990 and the Inter-modal Surface Transportation Efficiency Act (ISTEA) of 1991, air quality has been the most visible catalyst for changing the transportation planning and decision making process. These two Acts have pushed transportation professionals into considering factors that were often ignored in the past.

Ms. Siwek suggests that these air quality issues have tended to take precedence over other environmental issues. She further suggests that a broad range of environment concerns need to be addressed to help ensure that ITMS is implemented in an environmentally sound manner. Issues noted by the author include the generation of toxic and hazardous wastes, energy and other natural resource restraints, improving conditions for minorities and low income groups, strengthening communities, preserving historic and cultural resources, reinvigorating central cities, and preserving open space, vistas, agricultural land, endangered species, wet land habitat, and water quality.

The author points out that even if technology eliminates the air quality issue-and we hear stories of low emission vehicles-congestion will still be a concern. In addition, the other environmental and social issues will still need to be addressed. Thus, the paper stresses that it is important to focus not just on air quality, but on all the environmental and social concerns facing metropolitan areas today.

Ms. Siwek suggests that ITMS can be of help in realizing environmental goals only if environmental concerns are considered in two important phases of the ITMS process. The first phase involves planning, project selection, and design. The second phase includes implementation, maintenance, and operations. To enhance environmental concerns, it is critical that all modal considerations are fully integrated into both of these phases.

The author provides the following examples to illustrate this point. First, high-occupancy vehicle (HOV) access and egress, as well as other transit needs, should be considered as part of the arterial street and freeway systems. Further, consideration should be given to all modes, including non-motorized modes, in all travel corridors.

Environmental concerns should also play a central role in the second phase of ITMS. Complex trade-offs are often made in the implementation, operation, and maintenance process. Environmental concerns should be given adequate consideration in this process. The paper cites the issues related to NO, emissions as one example of the complex nature of this step. NO, emissions are lowest when vehicles operate at speeds under 15 miles per hour (mph). Emission rates increase at speeds over 15 mph, however, and increase sharply at speeds over 45 mph. If the intent is to manage NO, emissions, one policy might be to keep speeds below 45 mph. Accomplishing this may be difficult, however.

A recent report from the U.S. General Accounting Office (GAO) documents examples of successes and failures in the operation of traffic control systems. Although the report does document traffic signal and air quality benefits of properly installed and maintained signal systems, it is critical of systems that have not been maintained properly. For example, the ATSAC system in Los Angeles resulted in an 18 percent reduction in travel time, a 44 percent reduction in vehicle delays at traffic signals, and a 14 percent reduction in air pollutants. At the same time, many other signal systems are not maintained properly, and benefits are unrealized.

The paper concludes by pointing out the critical role ITMS will play in both short- and long-term solutions to transportation and environmental problems. Ms. Siwek further suggests that transportation and environmental professionals need to work together to ensure that this happens.

As a side note, I would also suggest that consideration be given to the urban development patterns that ITS may encourage. The emerging pattern may not help solve the long-term environmental and social problems noted earlier. If this is the case, we may wish to address some of these issues with the selective application of ITS. It is also important not to over promise with ITMS and ITS. At the same time, other strategies, such as land use, TDM, and selected improvements, should not be totally ignored.

The second paper, ***Multimodal ITMS: From Integrated Traffic Management to Integrated Transportation Management,*** is by Katherine Tumbull of the Texas Transportation Institute. This paper begins properly with the acknowledgement of the difficulty of implementing ITMS in a system of multiple agencies and jurisdictions. The paper is divided into four sections-the multimodal ITMS concept and its components, the technical and institutional issues associated with implementing ITMS, alternative implementation strategies, and the conclusions and suggestions for further research.

The paper notes that the ITMS concept began in many areas with centralized efforts to monitor and manage vehicle traffic on freeways. The system on the I-5 Freeway here in Seattle, which is called the FLOW system, is one example of this. There are many other examples of similar systems across the country.

The paper goes on to describe how the capabilities of these systems are being rapidly expanded with ITS. Transit and emergency services are now being included in the overall management of many travel corridors. The paper suggests that the ITMS concept must now be expanded to encompass all transportation functions-including toll facilities, non-motorized transportation, transit services, HOV lanes, parking, TDM, commercial vehicles, response teams, railroads, and land side access to ferry, airports, ports, and railroads. This is quite a list of elements to be integrated and quite a challenge to the transportation industry.

Thus, Dr. Tumbull suggests that the components of ITMS should include the entire transportation system. The paper provides an excellent inventory and detailed discussion of each mode and function. Examples are provided of current and proposed projects that incorporate these different elements into ITMS. I would urge you to read this part of the paper, as I do not have time to discuss each area in detail.

A common theme among all these components is the huge advantage the transportation industry can realize by sharing information. This is noted in the paper as being the key to providing cooperation in many other areas.

The paper next focuses on a discussion of the technical and institutional issues associated with planning, implementing, and operating ITMS. I will start with the technical issues, as this is an area which we may actually be able to address. As we all know, tbe institutional issues are often much harder to resolve. Many different technologies are currently being deployed, including loop detectors, closed circuit television, video imaging, and many other elements.

ITS promises to enhance our capabilities to collect and share information. Advances in technologies have been made not only in the highway mode. Transit systems throughout the country are using automatic vehicle location (AVL) systems to monitor the location of buses, to provide real-time information to passengers, and to improve system reliability and on-time performance. Railroad companies, as well as police and fire agencies, are utilizing a wide range of technologies to support their functions.

The challenge, of course, is to ensure that all these systems are compatible. Remember Granada? There were four service branches within one department, within one country, that could not communicate with each other as they were being invaded by the U.S. because they were using different radio frequencies. Imagine dozens, even hundreds, of agencies, as well as the private sector, trying to communicate on the system we are trying to design. Obviously, an excellent system architecture is required to facilitate this. The resource paper by Kerr and Mosley addresses the system architecture issues in more detail.

The national ITS system architecture is now under development by the U.S. Department of Transportation. A number of workshops have been held throughout the country to help facilitate this effort. How the communication systems will be linked together and whether a central facility or a networked distribution system will be developed are key questions to be resolved. I think the technical issues associated with ITMS can be solved if we defme the problems correctly.

The institutional issues may be a different story, however. Institutional issues are often not as easy to deal with, and we have a long history of problems with agencies working together. To help address these concerns, the paper suggests starting early in the process to build relationships among agencies and their staff. Establishing the roles and responsibilities of different groups is a critical early step in the process. The mix of public and private groups involved in ITMS make this an even more difficult process. Uncertainty or mistrust may exist among these groups and these issues will need to be overcome to advance ITMS.

For example, selecting a lead agency may be difficult. Many times the state department of transportation takes on this role. In other cases, a multi-agency group may be created to lead the ITMS implementation effort. The paper suggests, however, that in all cases, support from management is critical. The need for a project champion is also important. This champion should be someone who is a senior executive or manager that believes in the project, has the ability to get the needed resources, and helps keep you out of trouble-or at least gets you out of trouble when you get into it.

Along with a project champion, a strong project manager is also needed. This may be an absolute zealot, who works night and day to ensure that the project is accomplished successfully. It is this combination of a project champion and a project manager that I think will be needed to advance ITMS.

Funding is also a critical institutional element. It is often easy to diminish the importance of funding, but it should not be overlooked. The numerous agencies involved in ITMS may complicate funding cycles, grants management, and determining the fair share for different groups. The addition of private sector involvement in ITMS increases the complexity of funding issues. The numerous groups involved in ITMS also offer the opportunity to maximize funding and utilize innovative approaches to financing.

The paper notes that there are many legal issues to be addressed in the deployment of ITMS. These will be discussed more in the Tuesday morning session and in one of the workshops. Legal issues include resolving questions related to the ability of agencies to enter into agreements with other agencies, private businesses, and other groups. Liability, insurance, and privacy are other legal issues that may arise in ITMS. These are issues that often become critical in the implementation stage and can delay projects if they are not addressed early in the planning process.

Some areas have established separate organizations to deal with these issues. For example, Houston and New Jersey have developed new agencies with responsibilities for developing and operating ITMS.

Alternative implementation strategies are examined next in the paper. As mentioned previously, there are many ways to plan, implement, and operate ITMS. These range from one agency or a group of agencies working together in one area to multiple agencies in multiple areas linked together by different communication technologies. Regardless of the exact organizational structure used, the paper identifies three basic levels of sharing that may be considered. These are the sharing of information, the sharing of facilities, and the sharing of control. Accomplishing each step is more complicated and more difficult.

Although the sharing of information is the least threatening of the three, it is still very difficult to achieve in many cases. For example, local jurisdictions would like to know if a freeway is closed and 40,000 vehicles will be rerouted onto the local street system in their jurisdiction. Sharing information between a state ITMS and a local area can help address these types of potential issues.

The second level identified in the paper is sharing facilities and equipment. This might include sharing a central computer, fiber optic networks, or a facility where staff from numerous agencies interact on a regular basis. Accomplishing this level will require agencies to work closely together and may involve the sharing of financial and human resources.

Numerous approaches could also be taken at the third level, which involves sharing control. For example, one agency may be responsible for all of the regionally important components of the system such as the freeways and the major arterials. Control might pass to other agencies for minor arterial streets, downtown streets, and other system elements. The control of different levels and activities will need to be worked out by the different agencies. Sharing control represents the more difficult and threatening issues to be addressed in the deployment of ITMS.

The author suggests a logical progression from sharing information, to sharing equipment and facilities, to sharing control. All of these levels are appropriate for ITMS, and benefits can be realized at each level.

In the conclusion, the paper identifies technical and institutional issues that need further research. The bottom line, however, is that ITMS is important for maintaining the health and economic and social vitality of urban areas. Further, both papers emphasize that ITMS represents one of the last chances to significantly improve the transportation system. Setting aside past problems and focusing on the critical issues will be necessary to meeting the goals of ITMS and enhancing the transportation system.

Resource Paper-Disciplines that Make ITMS Work and Multi-Jurisdictional Issues in ITMS

Leslie Kelman The Municipality of Metropolitan Toronto

We will be discussing ITMS over the next two days. As part of this discussion, it will be important to identify what we mean by transportation management and ITMS. A transit agency representative may think transportation management should only help encourage more people to use public transportation. A bicycling enthusiast might suggest that it only means more people traveling by bicycle. The construction industry probably thinks it only means restricting vehicles from facilities during reconstruction. Pedestrians are interested in being able to cross roads and walk in a pleasant environment. Our job as transportation professionals is to bring all these ideas and perspectives together in a common vision.

I was asked to review and discuss four of the resource papers. *These* were ***ITS: Disciplines that Make it Work*** by Douglas Wiersig of the Greater Houston Transportation and Emergency Management Center, ***Multi-Jurisdictional Issues in*** ITMS by Matt Edelman of TRANSCOM in New Jersey, as well as the system engineering and architecture papers noted previously. I found all of the papers to be interesting and well done.

Rather than reviewing the papers one at a time, I would like to summarize the issues and elements common to all four. After reading the papers, I identified six common themes. These are

- ITMS vision
- Agency relationships
- Technical and informational architecture
- Public and political relations
- System expansion
- Other concerns

I will discuss how these issues were addressed in each of the four papers.

The visions presented in the papers were slightly different. In two cases, the vision focused primarily on a total system definition and design (top-down), and the integration of all modes and facilities into a system. Although not contradictory, the other two papers suggested a vision focusing more on developing a system that is responsive to local needs (bottom-up). In reality, we will not be able to achieve uniformity across the country. Rather we will continue to see different strategies utilized by various agencies and areas.

There was more uniformity among the papers on the issue of agency relationships. All four authors seem to be in agreement that no one agency had to be in charge for a regional coalition to function effectively. Further, the authors suggested that individual agencies have enormous responsibilities, budget pressures, and demands from the public, media, and elected officials. ITMS should focus on helping agencies fulfill their responsibilities and allow them to better meet the needs of their customers.

Further, it was suggested that regional coalitions focus on those elements that can be done better collectively than by the individual agencies and then doing them well. A point I especially liked in one of the papers was the importance of focusing on early success. Maintaining uncomplicated accounting and billing systems was also noted as important for building good relationships among agencies.

Technical architecture and informational architecture represents the third common theme in the four papers. It is important to remember that in most areas ITMS will build on existing hardware and software components. Most projects will not be able to start with a clean slate. Thus, the issue in many areas will be how to link existing systems together. The two papers focusing on system architecture and system integration do an excellent job of discussing these issues in terms that non-technical people can understand.

I was pleased to see the fourth area-that of public and political relations-brought up in the papers. It is important to remember that we are not working in isolation and that developing good relationships with the public and with public policy groups will be critical to the success of ITMS. Creating an early awareness of program activities and an ongoing communication mechanisms were identified as important elements in the

ITMS development process. Building on past successes and taking incremental steps were also highlighted in the papers.

The next common theme addressed system expansion. The need for a system design, guidelines, and documentation for expansion was suggested in the papers, while at the same time maintaining the flexibility to respond to changing ITMS responsibilities. Providing the ability to accommodate new and expanding technologies and disciplines was also noted as important particularly as ITMS responsibilities and functions can change over time.

I grouped a number of other issues relating to both the internal and the external environment into the final category. First, there is a need for transportation staff and system integration staff to find a common ground and to use a common vocabulary. Second, representatives from groups responsible for buses, taxis, and other modes need to be included in the early planning and design of ITMS. These vehicles can act as traffic probes to further enhance the flow of information about conditions on all roadways to the system. It is also important to resist the temptation of technology for the sake of technology. The temptation of “technology toys” should be avoided as it sends the wrong message to the public and to decision makers. Rather, we should be focusing on what ITMS can do to address real problems today.

I would like to provide a few additional thoughts on some of the issues raised in the resource papers. First, the potential for political pressure must be realized. Focusing on short-term, as well as long-term goals, and early successes can help address these concerns. Being able to tell decision makers what you have done for them today will continue to be important.

Second, I hope funding needed to initiate ITMS and for ongoing operating costs will be discussed in the workshops. The lessons learned from signal systems and the freeway network is that funding is often available for the initial capital costs but not for ongoing operations and maintenance.

Public/private partnerships is a third area I hope will be explored in more detail in the workshops. Innovative partnerships involving public and private sector groups will be one of the keys to the successful deployment of ITMS. This approach is much different from the historical ways we have done business, and we have a great deal to learn.

The rate of technological change, and the fallibility of master plans, should be also considered. Technology is evolving so rapidly that it is difficult to keep up with the latest systems. The Houston and New Jersey case studies illustrate the importance of building on the successful deployment of proven technologies.

In deploying ITMS, we should build on our experience during the implementation of other transportation systems and projects. The lessons we can learn include the fact that implementing improvements often disrupts normal operations, hardware is generally cheaper than the software needed to run the system, determining central or local intelligence and communication requirements will be an issue, staff involvement in the development and design is key, and a realistic approach should be taken to the design life of a system. A staged implementation process for ITMS is the most appropriate.

In Toronto, we have focused on different levels of integration. We started by integrating the signal and the freeway systems, which are both the responsibility of Metro. This was expanded to include the traffic systems and general traffic services, which are also under the direction of Metro. Traffic and road functions were then added, followed by the provincial roads, traffic, and police functions, and then transit.

In conclusion, the key focus for ITMS is to help agencies meet their responsibilities. This approach provides a more realistic focus rather than arguing over management and control functions. The approach we have used in Toronto is to focus on how we can help agency personnel do their jobs, rather than doing their jobs for them.

A number of elements can be identified for ITMS to be a success. First, successful systems are systems that work. They are also systems that are viewed positively by other agencies. An approach that focuses on working cooperatively with other agencies, rather than one focused on controlling or competing will be viewed more positively. Successful systems have political and public support, and they help meet the needs of agency customers.

Finally, I would like to offer an acronym-POTS and PANS-for your consideration. This stands for Partnerships in Operating Transportation Systems (POTS) and Public/Private Alliances and Networking for Success (PANS). I think these better reflect the approach that is needed in advancing ITMS. I am a little wary of the term integrated, as it often implies control. I would rather see the use of terms like partnerships, which better reflects what we are trying to accomplish.

Panel Discussion
Thomas Urbanik, II, Texas Transportation Institute
Tip Franklin, TRW, Inc.
Matt Edelman, TRANSCOM
Katherine F. Turnbull, Texas Transportation Institute
Sarah J. Siwek, Sarah Siwek and Associates
Jim Kerr, NET Corporation

Question: Many of the papers noted the importance of institutional issues. Do you have any suggestions on how to address these?

Edelman: There are a number of ways to address the institutional issues associated with ITMS. Engineers are trained to do things according to standards and rules, and not causing any problems. In ITMS, engineers may need to assume a much different role-that of creating change and developing new organizations, institutional arrangements, and systems. Engineers will need to be bolder and will need enhanced communication skills to make ITMS successful.

Turnbull: Thinking through potential institutional issues before you start planning and developing ITMS is critical. Identifying possible problems will allow you to take a proactive approach to addressing these. Involving the key players early in the planning process is also important.

Houston provides a good example of the development of a strong working relationship between Houston METRO, the transit agency, and the Texas Department of Transportation. The relationship between these two agencies has evolved over the last 15 to 20 years. This does not mean they always agree or that there are not problems, but they have been able to work through issues and have been able to move forward with a number of joint projects.

It is also important to remember that the institutional issues often come down to the people within different agencies establishing good working relationships. Personnel do change over time too. A group that worked well together 5 or 10 years ago may have changed as people move up in organizations or change jobs. As a result, ongoing attention should be focused on ensuring strong institutional arrangements and working relationships.

Siwek: One thing most of the cities in Los Angeles County can agree on is that they need funding from the county wide transportation authority for improvements. It is also fair to say that many of these cities have learned that they can be more powerful and can leverage more funding by building coalitions with other cities in a travel corridor or area. Thus, I would suggest communities work together and build on the elements that can be agreed upon to develop an initial system. Focus on what you agree on, not what you disagree on. Additional components, other modes, and other groups can be brought in as the system evolves and matures.

Question: Several of the papers talked about the need to get other modes and agencies involved in ITMS. Looking at the attendance list for the Symposium, it appears that only a few representatives from transit agencies, toll facilities, and other groups are here. A number of the case studies indicate that when you get these groups to the table, good things start to happen. How do you get these groups to the table initially?

Turnbull: The point was made earlier that personnel within most agencies are very busy taking care of daily operations and problems. A good place to start to get other groups involved is to show them the benefit of ITMS, and specifically how ITMS can help them do a better job and meet the needs of their customers.

To some extent this may be a promotional or outreach activity. One of the things that may be appropriate for discussion in the workshops is how we can do a better job getting other groups involved. This might include developing information on successful projects, especially those involving multiple diverse groups.

Once you get these groups to the table, the next step is to keep them there. This means involving them throughout the planning, design, and operations phases and making them an integral part of the process. The need to involve many diverse groups is critical to the success of ITMS and ITS.

Edehnan: One of the things I have found is that there is a middle ground to involving other groups. If you are too visionary and too aggressive, other groups will have an excuse to resent you as being an empire builder. If you are too weak and unfocused, they may question why you are bothering them. You need to find a middle ground that focuses on the specific needs of these groups. It also helps to find a few individuals in the different agencies who believe in the benefits of ITMS and are willing to work with you.

The involvement of police departments in TRANSCOM helps prove this point. We had worked to get numerous police departments in the New York, New Jersey, and Connecticut area to share incident information with TRANSCOM. Our efforts were not very successful until we found one police officer in the Bergen County Police Department. Once he began providing information on accidents on facilities within his jurisdiction, which was then shared with other departments, other departments became interested.

This approach is a lot like the movie ***Norma Rae in*** which Norma Rae believes in the Union and begins to recruit others. We need to find a lot of Norma Raes in different agencies and get them involved in ITMS. This happened to us in the case of the police departments and TRANSCOM .

Siwek: Two other points are important to remember in getting other agencies and groups involved in ITMS. First, the management system provisions of the ISTEA offer real opportunities for agencies to work together on these types of issues. Second, the financial constraint of the ISTEA also offers a catalyst to get numerous groups working together on ITMS and other projects. Transportation Improvement Plans (TIPs) and other plans can no longer be wish lists of projects. Rather the projects in the TIPS must be matched to available resources.

The other way to get groups to work together is not one you want to use, but it has happened so often recently in the Los Angeles area that it is worth mentioning; that is natural disasters and emergencies. When an earthquake hits or some other major problem arises, the public and policy makers want to hear what can be done, rather than what cannot be done. These types of problems tend to bring all groups together to work toward a common goal. The team work developed during these situations can often be continued on au ongoing basis.

Urbanik: It is also important to remember that the development of strong working relationships does not happen over night. The relationships in Houston have been developed over a 20-year period. A single project-the North Freeway Contraflow HOV lane-brought the state and city transit and highway agencies together. This project was a success, and this success lead to other projects, including the ITMS center and other ITS projects.

Question: Many transportation agencies lack expertise in system architecture and system integration. Are there any good examples or experiences that can be used to help those agencies?

Kerr: That is a good point. Typically, many state departments of transportation do not have a system engineer or even a computer engineer who could help with these activities. As a result, consultants will usually be needed to help with system engineering and system architecture. The big challenge is to overcome potential fears early in the process related to technology issues. The system engineering process is intended to be a simple method to step through from the basic requirements down to the system level. I think the challenge is for the traffic and transportation staff at state departments of transportation to express their needs in a way that can be implemented. The system engineer can then start thinking about the precise benefits anticipated from the system.

Franklin: I would agree with that point. I often get a blank look from transportation engineers when system engineering is mentioned. System engineering is not normally funded in a low-cost bid environment. Once you get beyond this, however, people realize that system engineering is just a common sense approach to building a system. It should also be realized that although system engineering is not a rigid process, it does provide structure to the system development process. System engineering helps ensure that the ultimate system meets the project objectives and is controllable and expandable. In most cases, it will be less expensive to use a system engineering approach because there will be fewer problems in the development process and with the final system.

Question: Given that many metropolitan areas already have different traffic signal system and other equipment, how can ITMS be quickly deployed?

Franklin: First, the objectives that each area wants to accomplish must be identified. The approach taken will depend both on the objectives of the system and the existing infrastructure in the area. ITMS involves a large capital investment. Existing systems and equipment can form the base of ITMS if future growth can be supported. A requirements document can be developed based on the capabilities of the existing system or it can be started from scratch. The requirements document can step through to the ultimate system. This approach may be especially appropriate with limited budgets.

Kerr: There are probably two major scenarios that would inhibit ITMS deployment. One would be when no infrastructure exists and a large scale effort is needed to initiate a system. The other case would be a region with a well developed infrastructure. Although this infrastructure may be the greatest attribute for the area, it may also be the greatest weakness. This would be especially true if the existing systems are proprietary in nature. One of the greatest challenges in ITMS may be overcoming the proprietary nature of many existing systems and technologies.

Question: What are the first steps that should be taken in the development of ITMS?

Franklin: One of the fist steps is to identify the goals and objectives of the system; that is what is expected from the system. Examining the basic responsibilities of the agencies involved is a good way to start this process. Once this step has been accomplished, you can start to determine the best way to meet this objectives. The experience with the 1984 Olympics showed that no one agency needs to be in charge for a system to function well. The key is to determine how to share critical information among agencies and groups, without giving up individual operating control.

Urbanik: There are a number of different elements that may be critical to the success of starting a new effort. In some cases, a project champion may be needed. The Houston case study highlights the success of the project champion approach. Houston also provides an example of taking advantage of opportunities that may emerge. For example, one of the HOV lanes was added to help traffic management during the reconstruction of a freeway.

Turnbull: Many areas have some type of multi-agency group in place that could be used to help advance ITMS. This might be a group formed as part of the activities of the Metropolitan Planning Organization (MPO), a corridor management team, or a special project team. Building on an existing, multi-agency group is a good way to start identifying the need for ITMS and the opportunities and issues associated with developing a system. If a multi-agency committee does not exist in an area, contacts between agency staff can be used as a starting point to develop one.

Question: What implications do you think the current political climate has for ITS and ITMS?

Siwek: I think ITMS and ITS offer tremendous opportunities to address many of the critical problems facing metropolitan areas today. They can further help address environmental issues. As such, there should continue to be support for ITMS and ITS. There may be less of an emphasis in the future on the use of command and control approaches to reducing emission through transportation investments, however. It is important to remember that even if the air quality issues are solved, there are still major congestion problems in most metropolitan areas.

Edehnan: While clean air is certainly one of the benefits of ITMS, it is not the only benefit. If you asked the groups involved in TRANSCOM, they would probably note the major benefit from the system is that it helps them do their job better. They might note clean air as a further benefit, but not the first.

Question: What are the financial implications of ITMS and what are potential funding sources?

Edelman: ITMS both costs money and saves money in the short-term and the long-term. In the area of construction coordination, it probably saves money to share one common database among three states, as is done in TRANSCOM. This represents a more efficient use of resources. TRANSCOM also functions as a test bed for operational tests and demonstrations. Additional funding will be needed to expand and continue operations, however. Funding will certainly continue to be an issue in most areas.

Franklin: One of the key elements of system engineering is to identify external constraints. Funding is usually the major constraint on most projects. To help keep costs reasonable, it is important to focus on realistic goals and objectives. A phased implementation approach can then be used to develop the system in an incremental way.

Question: How does congestion pricing fit into ITMS?

Siwek: There are a number of congestion pricing demonstrations currently being funded by FHWA. All of these are in the planning stage, however, so there is still no real experience with congestion pricing in this country. I believe that all of the demonstrations are considering ITS technologies as part of the project infrastructure.

Edelman: Congestion pricing cannot realistically be implemented without ITS and a regional coalition. Political support will be needed to implement any type of congestion pricing system. A regional coalition and ITS will also be needed to make it work.

Question: Are there any examples of ITS and remote vehicle emission testing?

Siwek: There has been a remote sensing demonstration project in California, but the results are not yet available. There is also a study that estimated the emission reduction potential of automating the toll collection on the Garden State Parkway in New Jersey.

PLENARY SESSION-Benefits of ITMS

Jeffery Lindley, Federal Highway Administration-Presiding

Benefits of Early Deployment from a Core Infrastructure Perspective

James ***Wright, Minnesota Department*** of ***Transportation***

My presentation will focus on the experience in Minnesota with the benefits of ITMS from a core infrastructure perspective. The FHWA has identified seven basic elements of the ITS core infrastructure. These are freeway surveillance and management, arterial signal control, incident management, vehicle location for transit, toll roads, electronic payments, and traveler information systems.

I would like to review the Minnesota experience with each of these different elements, the current status of activities, and the benefits that have been realized to date. First, the Minnesota Department of Transportation (MnDOT) has developed a fairly extensive freeway surveillance and management system in the Minneapolis-St. Paul metropolitan area. Currently, this system includes almost 400 freeway ramp meters, 156 closed circuit television cameras, 3,000 loop detectors, 39 Autoscope cameras, 51 changeable message signs, and 90 freeway emergency call boxes.

Expansion of all these elements are planned, with the exception of the call boxes. This program may be phased out due to the cost of operating and maintaining the system and the proliferation of cellular telephones, which appear to be more effective. In addition, a system of fiber cable is being installed. Roughly 100 miles of a planned 250 mile fiber system has been implemented. This system will connect the MnDOT operations center, the transit operations center, the City of Minneapolis, and Hennepin county. A Highway Radio Advisory (HRA) is also operated out of the MnDOT center.

A number of benefits have been realized from the implementation of all these elements. The capacity of the freeway system has increased to upwards of 2,200 vehicles per hour per lane. Speed increases averaging 12 miles per hour has been realized on the freeways. The number of accidents have been reduced by over 100 per year. Savings in fuel consumption and vehicle emission reductions have also been realized. Finally, a savings of $1 million per year in user benefits has been estimated based on reductions in accidents and congestion levels.

The traffic signal control system is the second core infrastructure element. Currently, there are approximately 2,200 traffic signals in the Minneapolis-St. Paul metropolitan area. These are operated by eight different jurisdictions and include fixed time, actuated-isolated, actuated-interconnected, and adaptive control signals. In addition, a portable traffic management system has been field tested. This system includes closed circuit television cameras, changeable message signs, and the ability to tap into signals to change the timing sequence.

It is a little difficult to quantify the benefits from these systems, especially those still in the early stages of deployment. The benefits of the SCOOT signal system, compared to the "best effort" fixed time optimization has been identified, however. Some of the benefits identified for the approximately 70 signals in the SCOOT system in Toronto include an eight percent decrease in average travel time, a 22 percent average decrease in vehicle stops, and a 17 percent average decrease in vehicle delay. Related reductions in fuel consumption and vehicle emissions were also estimated.

I would next like to summarize the status of incident management activities on freeways in the Minneapolis-St. Paul metropolitan area. There are two major components to the incident management system. The first is the Highway Helper program. This provides assistance to motorists weekdays from 5:00 A.M. to 8:00 P.M. on the major freeways in the metropolitan area. The Highway Helper program has resulted in numerous benefits. Approximately 15 percent of all accidents in Minneapolis are secondary accidents. If we can reduce exposure to accidents, we should be able to reduce these secondary incidents. There is also a 4:l payback ratio with the program. This means if you can clear an accident five minutes sooner, you will cut 20 minutes in related congestion delay downstream.

A towing policy has also been implemented. Under this policy, private tow trucks are immediately dispatched to the scene of an accident. This program has cut the average response time in half, or to approximately 20 minutes. The Highway Helper program provided some 13,000 assists last year. This program is very well received by the public and is one of MnDOT's most visible efforts.

Currently, there is no system for incident management on arterial streets in the area. There are two planned field tests, however. The first, called Divert, is in downtown St. Paul. This system will use 10 closed circuit television cameras, four changeable message signs, and HAR to help manage traffic during special events. Divert is scheduled to be operational this year.

The second project will be implemented in the I-494 corridor near the airport and the Mega Mall. This system will use eight closed circuit television cameras, 12 variable message signs, two portable variable message signs, and HAR to manage traffic on two parallel arterials .

The next core infrastructure component is AVL for transit. A Global Positioning System (GPS) AVL system is being implemented in the area. The hardware elements have been installed, and 80 buses have been equipped with AVL. These buses are operating in the I-394 corridor. Real-time information on the status of buses is being displayed at the transit stations and at park-and-ride lots in the corridor. This feature has been well received by the public.

Another part of the project includes three kiosks located in downtown Minneapolis providing real-time transit and traffic information. The next step, which will begin this summer, will deploy terminals in commuter's homes and businesses in the I-394 corridor. We hope this will result in increased transit ridership. Potential benefits of the AVL system include better fleet management, fewer on-street supervisors, improved schedule adherence, and improved safety for operators and riders.

In 1993, the Minnesota legislature authorized toll roads, and in 1994 a road pricing study was mandated. The potential for pricing use of HOV lanes single-occupant vehicles is also being examined. We hope to issue a request for proposals (RFP) for major toll road projects in July and select projects by December. The potential benefits of toll roads include additional revenues, dedicated funds for specific locations and uses, faster construction and development schedules, and establishing a revolving fund to match federal funding.

The next core infrastructure area is electronic payment. A number of parking projects are currently being developed in the metropolitan area. First, the City of Minneapolis has recently implemented 100 parking meters that use pre-paid debit cards and debit keys for payment. The system also clears any remaining time on the meter as a vehicle leaves the parking space. The city estimates that this system will result in a 10 percent increase in parking revenues.

The Minneapolis-St. Paul International Airport parking facilities include 10,000 spaces and account for some $3 million in annual transactions. The license plates of all vehicles parked at the airport ramp are recorded electronically each night. Vehicle license plates are also read as a vehicle leaves the parking garages, and the required parking fee is automatically produced. This system has increased revenues and has decreased parking fraud.

The taxis and hotel vans at the airport have recently been equipped with automatic vehicle identification (AVI) tags. The goal of this system is to maintain a maximum of 15 taxis in the terminal queue at any one time. Other taxis wait off site until they are called. Special vehicles-such as station wagons or vans-can also be called by the system. Taxi fares can also be paid by credit cards.

Another element of the airport transportation plan is to limit the time hotel vans circulate or stand at the airport terminal to 10 minutes. The fee for these vehicles to enter the airport is currently $.75 If a hotel van is in the terminal area for 11 to 21 minutes, an additional $1 .OO is charged. After 21 minutes, the parking fee goes up to $2.00. These charges have not been implemented, however, as hotels are adhering to the 10 minute limit. The system will be implemented if congestion becomes a problem.

A number of traveler information systems are being implemented in the metropolitan area. MnDOT's HAR currently broadcasts during the morning and afternoon peak-periods. The HAR covers 829 square miles of the metropolitan area. The HAR is well listened to and appears to fill an important need.

A number of ITS Operational Tests and Field Trials are underway in the area. These include Travlink, Genesis, Trilogy, an advanced parking information system in downtown St. Paul, and an in-vehicle navigation system.

Polaris is the traveler information system which really brings all of the these elements together. It includes the development of a statewide ITS architecture; a statewide deployment program focusing on paging, cable television, and use of the Internet and World Wide Web; a road weather information system in rural parts of the state; and the mall concept of privatization. This concept equates the deployment of the different ITS components to a mall manager and individual stores. MnDOT will act as the mall manager to establish the standards and protocols, and the private sector-or individual stores-will then provide the different user services.

In summary, the MnDOT freeway management system has resulted in a 20 percent increase in capacity and an increase in freeway speeds of 12 miles per hour. The adaptive signal control system provides an 8 percent decrease in travel times over isolated signal systems. The incident management system has resulted in significant time savings in responding to freeway accidents. We anticipate that the other core infrastmcture components will be equally beneficial.

Dallas Urban Area Integrated Transportation Systems

James D. Car-veil, Jr., Texas Transportation Institute

The experience with freeway corridor traffic management in the Dallas area started in the 1970s. In 1973, meters on 34 freeway ramps were implemented in the North Central Expressway. In addition, 15 intersections on the frontage roads were controlled by a central computer for bus priority. Trailer mounted matrix signs, rotating drum signs, and a two channel telephone system, which provided information on freeway conditions, were also part of the system.

This system worked well. The test data indicated that freeway speeds increased by 15 percent and delay time decreased by 15 percent. Bus travel times decreased by some 10 percent. This system was not continued, however, for a number of reasons, not the least of which was a commitment of sufficient resources for operation and maintenance. Thus, rather than presenting the benefits of an existing system, my comments will explore how the Dallas area is working to develop a new transportation management system and the anticipated benefits from this system.

I think one of the key benefits of working toward the development of ITMS is that it requires a focus on regional transportation goals. There are 33 municipalities in the Dallas area. Eight of these have populations greater than 50,000, with five of these over 100,000. These municipalities may have different operational goals, but working toward the deployment of ITMS requires a focus on regional goals and objectives.

At the same time, ITMS can accommodate jurisdictional independence. Smaller communities may be concerned that larger cities or the state will take control of traffic operations in their community. ITMS can accommodate jurisdictional differences and operation plans can be developed to serve the needs of all communities.

ITMS also provides the opportunity for a more nearly seamless traffic signal system. Certainly ITMS contributes to the goals of the Clean Air Act Amendments and may have other environmental benefits. By combining funding from numerous local sources, ITMS may help leverage additional federal funds for an area. ITMS can also minimize duplication of effort by effecting shared resources.

ITMS also helps foster inter-jurisdictional communication and cooperation. In most areas, including Dallas, multi-agency teams are being used to coordinate the development and ongoing operations of these systems. This communication and coordination can spill over to other projects and helps build closer working ties among the different groups involved in ITMS.

I would like to briefly discuss two projects in the Dallas area the provide examples of these benefits. The first is the North Dallas County Integrated Traffic Signal System project. The goal of this project was to improve traffic service by coordinating signal operation across jurisdictional boundaries.

The project area is a heavily traveled corridor in North Dallas County. There were 224 traffic signals in the corridor operated by six jurisdictions. Most of these were actuated signals. When the project began, there was minimal coordination within the cities and none across city limit lines.

The project objective was to erase the city boundaries with respect to the traffic signal system. Thus, the effort focused on traffic operations. The City of Dallas took the lead on coordinating this effort. Working with the **other** cities, the program was presented as a county-wide effort and a bond referendum was passed by the voters to fund the system.

An engineering consultant was hired to develop the timing plans for the corridor. Each city procured the necessary hardware and controllers with their own specifications with the coordinating committee performing a review and approval of disbursements function.

This system has resulted in numerous benefits. Travel time in the corridor has been reduced by six percent, vehicle delay time has been reduced by 34 percent, and stops have been reduced by 43 percent. The estimated reductions in fuel consumption and emissions is approximately 5 percent, and the estimated annual benefits are $26 million at a cost of $4 million. I think one of the real benefits of the project is that it showed that Dallas County could undertake a multi-jurisdictional effort and that the County and the six cities with differing goals and priorities could work cooperatively. As a result, the next bond election extended the program to other parts of the County and established $4 million in seed funding for an incident response center.

The second project I would like to talk about is the development of an inter-jurisdictional ITS Implementation Plan for the Dallas area. This effort grew out of the Dallas County Integrated Traffic Signal System project. The multi-jurisdictional working group from the traffic signal project was interested in continuing their joint efforts to develop an ITS early deployment plan.

The area included in the early deployment plan covers a much larger area, encompassing approximately 400 square miles. The 25 member project steering committee includes representatives from the several cities, the Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART), the private sector, and other groups. The advisory committee meets on a monthly basis. A series of one-day workshops have been held to discuss major issues and to identify appropriate approaches.

Major issues being examined in the early deployment plan include institutional concerns, inter-jurisdictional issues, formulation of a system architecture for the area, and development of an ITS implementation plan. Integrating local traffic signals during incidents was one of the fust major issues to be addressed. The approach agreed upon by the Steering Committee is that TxDOT will operate a central management and information processing system and that the cities will implement predetermined signal timing plans in response to specific incidents. Data and information will be stored among TxDOT, the cities, and the private sector.

A second workshop focused on on-site incident management. The keys to success of Integrated Transportation Systems include the early involvement of all affected agencies, monthly meetings of the steering committee, open discussion, ongoing communication with all affected groups, and fostering participation of all agencies. In addition, I think the mutual respect the members of the steering committee have for each other has been an important element.

Finally, a committee workshop produced guidelines for the deployment of hardware and management systems.

Montgomery County, Maryland
Gram Norton, Montgomery County, Maryland

A question was asked earlier about how to initiate the development of ITMS. I would like to explain how we got started in Montgomery County, Maryland, and provide an overview of our current system. I will close my presentation by outlining our future vision and the next steps in the deployment process.

In the late 1980s a truck carrying what was believed to be hazardous material overturned on a freeway in the county. The facility was closed for 17 hours while the different agencies responsible for hazardous materials, public safety, enforcement, and freeway operations responded and cleared the incident. The media provided a full review and audit of the situation. As one can imagine, the results of the review were not very complimentary to the way the incident was handled.

The political leadership in the area decided that this type of situation should not be repeated and started the process to develop coordinated incident response teams. The use of advanced technologies became an integral part of this process.

Montgomery County is located just to the north of Washington, D.C. The county covers some 500 square miles and has a population of 800,000. Montgomery County is a "full service" county, in that the county provides a full range of municipal services. There are only a few incorporated municipalities in the county and 80 percent of the population lives in incorporated areas.

There are 350 miles of state roads in the county, along with 2,200 miles of county roads. The county is responsible for all of the traffic signals on the state road system. Because of the county's location between Baltimore and Washington, D.C., a great amount of traffic travels through the area on the three major travel corridors. All of these corridors are congested and traffic volumes are projected to increase.

Until the 1980s, travel patterns in the county focused primarily on work travel into and out of the Washington, D .C. area. As a result, the county has an excellent transportation and transit system serving this commute pattern. The growth in travel in the 1980s occurred primarily within the county, however. Today, over 60 percent of the work trips begin and end within the county. The new travel demands developed in both a starburst pattern and in an east-west pattern. The transportation infrastucture was not developed to support these travel demands.

The development of a computerized centrally managed traffic signal system began in the 1980s. The traffic management center also became a reality during this time. The first element of the center was managing the 660 traffic signals in the county.

The county experienced a fiscal crisis in the early 1990s, similar to many other municipalities around the country. This resulted in a loss of both capital and operating funds. For example, the six year roadway capital program for the county was as high as $320 million in the late 1980s. The six year budget recently submitted contains only $88 million for the roadway program. Thus, it became apparent that funding was not available to expand the roadway system. Automated traffic management and other ITS activities became a key focus for the new approach to address the transportation problems in the county. There was strong political support for the development of these systems.

The transportation management system in Montgomery County includes a number of elements. The county leases an airplane which is in the air during the morning and afternoon peak-periods. The information from this air monitoring program is provided directly to the center and to the fire rescue service and the police department. In fact, the pilot is a retired police officer.

The emphasis in the early 1990s was on gathering information to help manage the system. Incident detection and response were major elements of the system and many of the benefits Jim mentioned concerning the MnDOT traffic management system were realized in

Montgomery County.

The county also operates a bus system, Ride-On, which carries approximately 50,000 passengers daily. Metrobuses also operate in the county. A little over a year ago, the dispatchers from the two bus facilities were relocated to the transportation management center. The initial impetus for this move was to provide the transit system with better information on current traffic conditions. It soon became obvious, however, that the 200 buses operating throughout the county could also provide valuable information to the center. Much more information came in from the bus operators than went out to them.

It was at this point that we made the consensus decision to move from traffic management to transportation management. The effort to fully integrate transit into the center was initiated at this point. The automated traffic management system became the automated transportation management system with the integration of transit.

A GPS-based AVL system is being implemented with the Ride-On bus system. Currently, one bus is equipped with the AVL technology. A 50 vehicle pilot project will be in operation by the end of the year and the county recently received a grant from the State of Maryland to equip the full fleet.

On December 28, 1993, another significant event occurred. The first of seven major snow and ice storms hit the east coast that day. Prior to the storm, the county had installed six video cameras at key intersections on the arterial street system. The capability also existed to broadcast live from these cameras on the county cable television channel, although we had never used this connection.

During the snow storms, the conditions at the six intersections were shown live on the cable channel. The reaction the public information office received on this coverage was very positive. Based on the response, it was decided to continue this service on a regular basis. Today, two hours of live coverage are provided every morning and afternoon on the conditions at 16 intersections, accidents, incidents, the status of the transit system, and other elements. The channel is also pre-empted during major snow emergencies and additional information on plowing, sanding, and road conditions is provided.

Thus, the Montgomery County system has expanded from just collecting information to managing the transportation system, to collecting information to manage the system and to provide it to the public. This information is helping individuals to make informed travel choices. All possible ways of communicating with the public are being considered.

The airplane used by the county has been equipped with a video camera and live coverage can be provided. The county also operates two traveler advisory radio stations. Planning is underway to provide information through the Internet and through personal computers. The county system will be linked this month to the State of Maryland’s Chart system and information will be shared between the two systems. Further, there are plans underway for a Capital Beltway Coalition that would expand the linking capabilities of the system.

There are a number of reasons why ITMS is approximate at the county level. ITMS can enhance the efficiency of the transportation system-both roadways and transit-and it can improve safety and security by providing improved incident detection and response capabilities. Finally, ITMS can provide critical information to the public to make informed travel choices.

Expenditures to date on the traffic signal and roadway elements of the system have been in the range of $8 to $10 million. Another $4 million will be invested in the bus AVL system and other transit components. Although much of the system has been funded with federal and state funds, communicating the benefits of the system to the local decision makers has been a critical part of our effort. We have taken elected officials up in the airplane and given numerous tours of the center. Broadcasting live on cable television has been one of the best methods for obtaining political support for the system.

The overall benefits of the system include getting greater efficiency out of the transportation system, providing enhanced incident detection and management capabilities, improving the safety of the different facilities, and providing greatly improved information to our citizens. The Montgomery County transportation management system represents a critical element to help meet the future travel demands in the area.

PLENARY SESSION-ITMS Case Studies

Catherine McGhee, Virginia Department of Transportation-Presiding

The Monroe County, New York Case Study

Frank Dolan, Monroe County, New York

I will focus my remarks this morning on the institutional issues associated with the development of ITMS and how these concerns are being addressed in Monroe County, New York. Monroe County is located on the south shore of Lake Ontario, about 70 miles east of Buffalo.

Integrate, as defined in the dictionary, is to form, coordinate, or blend into a functionor unified whole. The whole focus of this Symposium is to learn how we can bring together all of the groups that will need to be involved in ITMS to enhance the overall transportation system.

One of the major institutional issues in New York relates to the state vehicle and traffic law, which grants the authority for traffic control on roadways to various jurisdictions. In cases where two jurisdictions conflict, such as the intersection of a state highway and a county road, the higher level, or the state in this case, would have control. In Monroe County there are 32 local governments. As a result, conflicts over traffic control may emerge among the state, county, and local communities.

The approach utilized to address these issues in Monroe County was initiated almost 25 years ago. In 1971, the County Executive and the Mayor of the City of Rochester agreed to develop a coordinated strategy for traffic management that would cross jurisdictional boundaries. A formal agreement was established between the city and the county giving the county responsibility for traffic engineering on both the county and the city roadways. The county also assumed funding responsibilities for all of the traffic functions.

Based on this success, the County Executive invited the 20 town governments to participate in the program. I think one of the keys to the approach taken by the county was to invite-not to force-participation. Although many of the 20 townships did not agree to participate initially, primarily over concerns related to maintaining their authority over the local road system, today all are part of the coordinated system. With the exception of signal maintenance which is done upon request, the county provides all of the traffic engineering functions for the 20 townships upon request. This represented the second step toward the development of ITMS in the county.

The third step occurred in the mid-1970s as a part of the TOPICS program. The TOPICS program was used to develop a UTCS traffic signal system to integrate the state, city, and the county traffic signals into one system under the authority of the county. The key to this system was an agreement with the New York State Department of Transportation to reimburse the county for the operation and maintenance of the state traffic signals. This agreement has been a critical element of the success of the system. Although staff within the different agencies and jurisdictions have changed, the agreement has not. Thus, the agreement represents the backbone of the working relationships among the various groups. The agreement also contains specific requirements for maintaining certain levels of operation and maintenance of the system. These requirements have helped maintain the integrity of the system during times of budget retrenchments.

Although some speakers have suggested that formal agreements may not be needed, from our experience I would encourage the use of formal contracts or written agreements. To paraphrase the poet Robert Frost, who wrote that “good fences make good neighbors”-we think that good agreements also make strong ongoing partnerships.

Building on the success of these initial efforts, the next step was to move forward toward au integrated system. This included coordinating the freeway and expressway systems, as well as integrating the system with the emergency services, the police departments, and other agencies.

As other speakers have noted, it is important to build on successful projects. Our first success story started with a major interchange project that is referred to as the Can of Worms. There were concerns that the construction of this project would cause major traffic congestion and other problems. Using a coordinated approach, that included transit agencies, police, emergency services, and other groups, we were able to avoid any major problems with the construction of the interchange.

All of these groups were involved early in the planning process for the interchange. Each phase of the project was discussed and the responsibilities for different activities were assigned. Items addressed included incident management, public information, construction phasing, traffic rerouting, and other issues. This approach worked very well and no major problems were encountered during construction.

The County Executive and other decision makers were very impressed with this process and supported the continued development of an integrated transportation management system. The County Executive took the lead in forming an Expressway Committee within the county to promote an integrated approach. The committee is comprised of representatives from the State Department of Transportation, the County Department of Transportation, the Rochester MPO, City and State Police, the County Sheriff, and local police departments. There are 11 different police departments in the county. These are represented on the Committee through the Public Safety Department. A Town Supervisors Association was also formed to help keep elected officials informed on the status of various projects. Representatives from the Industrial Management Council and the American Automobile Association are also included on the Committee, which meets monthly. This Committee has been active in the development of ITMS in Rochester. The State Department of Transportation is the lead agency in this effort and Howard Needles is the consultant on the project to develop an integrated system.

Some people may ask why we are pursuing ITMS in Rochester. Our average commute time is about 20 minutes and the level of service on most freeways and arterial streets is acceptable. This is a nice situation to be in. We want to maintain this situation, especially given the importance of the transportation system to businesses in the area. Rochester is the home to Kodak, Bausch & Lomb, Xerox, and many other companies. Just-in-time delivery and making intermodal connections are very important to these businesses.

With Kodak, the Rochester area is known as the photography capital of the world. As a result, our ITMS is going to be called the Image System. We will be using an incremental process to develop the system. The use of variable message signs and closed-circuit television cameras on the freeway system will be the initial focus of the system. Rochester also gets numerous snow storms and we get about 90 to 100 inches of snow a year. These storms can hit very quickly and can cause havoc on the freeway system. The variable message signs will be used to provide early warnings to motorists and truckers about snow and weather conditions. In addition, consideration is being given to pavement and weather monitoring systems.

We are still in the early planning stages for the system. We plan to continue to work with all the different groups to ensure a coordinated approach. This will include the involvement of the key stake holders and the development of a clear vision and a mission statement. This will help ensure that everyone has a clear understanding of what we are trying to accomplish. We thii the system will be critical for maintaining the economic health and vitality of the area, as well as enhancing the mobility of area residents.

TRANSGUIDE in San Antonio
Russell Henk, Texas Transportation Institute

It is a pleasure to have the opportunity to talk about the 'I'RANSGUIDE project in San Antonio. While Pat Irwin and Pat McGowan from the Texas Department of Transportation (TxDOT) deserve the majority of credit for the success of the project, neither of these gentlemen were able to attend the Symposium. It is an honor to be asked to fill in for them and provide you a brief overview of the TRANSGUIDE project in San Antonio.

In the spirit of the ITMS Symposium, I will use a multimedia approach with my presentation. I will first show a video which explains the TRANSGUIDE project. The video was prepared by TxDOT's public information consultants. It has been used very effectively in public meetings and presentations to different groups. After the video, I will provide an overview of the current status of the project.

Highlights from the video:

- TRANSGUIDE, which is short for the Transportation Guidance System, brings together a combination of road sensors, video cameras, changeable message signs, other advanced technologies, and people to better manage traffic on the freeways in San Antonio, Texas.

- To motorists, TRANSGUIDE will mean better traffic flow, less delay due to congestion, safer and easier driving, and faster response to accidents.

- The Operations Control Center contains three large video walls that can display maps, current traffic conditions, and changeable message signs, to help operators monitor traffic flow on the freeways and respond immediately to problems.

- The control center also contains individual consoles for 18 operators (with room for additional expansion, should the need arise). The Operations Control Center acts as a clearinghouse. Preprogrammed solutions can be activated in response to incidents and other problems.

- Road sensors, that provide data on traffic flow, provide the basic input to the system. Eight hundred road sensors and 52 closed circuit television cameras have been installed along approximately 27 miles of freeway. These are linked by some 50 miles of fiber optic cables and connected to computers at the Operations Control Center.

- Overhead lane signs and changeable message signs will be used to communicate with motorists. Within two minutes of an accident, the Operations Control Center will be aware of the situation, and the appropriate response will be initiated.

- The Texas Department of Transportation (TxDOT) is responsible for the design, development, and operation of TRANSGUIDE. Other agencies, including emergency personnel, will be located in the Operations Control Center, however, allowing for immediate response to all types of incidents.

- The initial system covers portions of I-10, I-35, I-37, U.S. 281, and U.S. 90. The system will eventually be expanded to cover some 191 miles of freeways in the San Antonio area.

- TRANSGUIDE will also form the basis for future advanced travel information systems in the San Antonio area.

The important role a project champion can play in helping to advance ITMS has been noted by other speakers. In San Antonio, TxDOT assumed this role. TxDOT took the lead in developing the initial concept for the system and in moving it forward to reality. To accomplish this objective, TxDOT had to address the three T's-turf, threats, and trust-related to institutional issues. To address these concerns, TxDOT undertook a major public information effort, as well as building links to other agencies. VIA Metropolitan Transit Authority, the City of San Antonio, Bexar County, and the police, fire, and EMS were all involved in the process. TxDOT promoted the benefits of TRANSGUIDE to these different agencies. This approach was well received at the staff level. There were still numerous issues related to funding, implementation, and operation which had to be addressed, however.

The TxDOT San Antonio District committed 30 percent of their annual construction budget to design and develop the ITMS. Although there was no initial commitment of funds from other agencies, the system was designed with the flexibility to meet the needs of other groups.

Once the central control center was under construction, support for the system began to grow. Most of the key agencies in San Antonio have now begun to commit funds to aid in the operations and maintenance of the system. The first phase of the TRANSGUIDE system covers approximately 27 miles of the freeway system and includes the control center, as well as the numerous loop detectors, cameras, lane control signals, and changeable message signs mentioned previously in the video. The cost of the first phase was approximately $32 million. A 60-day acceptance testing period has been initiated, and the system should be fully operational by the end of July. The ultimate system will cover approximately 191 miles of the freeway system in San Antonio.

The real challenge in the future will be to integrate this freeway-based system with the arterial roadway system and other transportation modes. This issue will be examined in an early deployment project which will be initiated this fall.

The North Seattle ATMS Project

David Berg, Washington State Department of Transportation

I would like to give you an overview of the North Seattle Advanced Traffic Management System (ATMS) project. A paper is available which provides more detail on the project and related activities in the Seattle area. The North Seattle ATMS project is a joint effort involving 14 agencies in the Seattle Area. A major focus of the Washington State Department of Transportation (WSDOT) has been on improving the overall management of the transportation system. The North Seattle ATMS project involves the $1.4 billion reconstruction of the I-90 Freeway. Given limited funding and environmental concerns, this type of project is really a thing of the past.

The North Seattle ATMS project was conceived in the 1980s as a way to share information among the various agencies responsible for different aspects of the transportation system. In the past, the major focus of this type of project has been on the freeway system. The North Seattle ATMS project broadened this focus to a regional basis. This larger scope obviously involved the need for additional funding, and increased the potential for institutional and operational issues.

As I noted, there are 14 agencies involved in this project. These include very large agencies, like WSDOT, and smaller organizations. The number of personnel and their expertise vary greatly among the agencies, as do available fmancial resources. In addition, each agency has a separate policy board as well as different priorities, objectives, and constituents. Coordinating the sharing of information among these different agencies is a challenging opportunity.

The North Seattle ATMS project has three main objectives. The first objective is to develop and implement a regional monitoring and information sharing system. The second objective is to develop and implement a coordinated approach to operations between the various jurisdictions, and the third objective is to ensure that the system can be used as a test bed for future ITS applications.

A number of regional issues had to be considered in the development of the communications architecture for the project. In developing a framework for the communications architecture it was necessary to look not just at the North Seattle area, but at the whole Seattle metropolitan area. The communications architecture focuses on a geographically distributed system, which allows individual agencies to maintain control over their own systems. At the same time, the system will allow access to shared information and links to other agencies.

The North Seattle ATMS system will initially use remote interface units at the different agencies. The key element of this system will be a communications backbone that can be supported throughout the region. The Electrical Engineering Department at the University of Washington has proposed an approach using the standards and protocols of the Internet. Developing a network on a client/server basis will help ensure that the various agencies retain autonomous use of their own individual systems. This approach also allows for future enhancements. Both public agencies and private enterprises should be able to link into the system with new technologies and new projects. We want to ensure that the system provides for future growth and development opportunities.

The need for a common communications architecture with this type of project is critical. We want to ensure that the system developed for this project is compatible with the approach and the needs for the full metropolitan area. Basing the architecture for the North Seattle ATMS project on the approach needed for the full metropolitan area will make future expansion easy.

There are also a number of institutional issues that have had to be addressed in the North Seattle ATMS project. Since the sharing of information among groups is central to the project, we had to be sensitive to the concerns of smaller agencies over possible loss of control. Although the different agencies were supportive of interjurisdictional cooperation, there was still a concern over the possible loss of control and authority. These are real issues that must be addressed with these type of projects.

ITMS projects have focused on heavily congested metropolitan areas. Questions have been raised concerning the benefits of ITMS for smaller agencies and communities. Explaining the benefits of ITMS to smaller agencies and communities on the fringe of major metropolitan areas will be critical to the successful deployment of these systems.

We have also had to address a number of operational issues. One of the major operational concerns revolves around the development of interjurisdictional coordination plans for traffic signals. Issues that need to be addressed include how the plans are developed, the responsibilities for maintaining and operating the system, and how changes and modifications will be made. Dealing with multiple types of equipment is also a key operational issue. The North Seattle ATMS project will focus on linking existing traffic signal systems rather than requiring a new uniform equipment. At the same time, we plan to incorporate some of the new national standards when they become available.

The Washington State Department of Transportation is the overall project manager for the North Seattle ATMS project. Our prime consultant is Farradyne Systems, Inc., out of Rockville, Maryland. I want to stress, however, that this is not just a WSDOT project. All of the agencies involved are stakeholders in the project. These agencies are the end users of the ATMS system and the project would not be a success without their involvement throughout the process. A major portion of the consultant's scope of work is to identify, develop, and implement the base user requirements needed by all the agencies. In essence, the agencies are our customers and their involvement is critical to the success of the project.

Another critical success factor is ongoing communications and regular meetings of all involved groups. The regular meetings provide the opportunity to keep all groups actively involved in the project and informed on the status of different elements. So far the user requirements have been developed and the base requirements have been identified. Working papers, draft reports, and other items are reviewed and discussed and we make sure all comments and concerns are addressed. The meetings are also used to give direction to the consultants and to help ensure the project is on schedule.

A second level group – called the Steering Committee – has also been used on the project. The intent of the Steering Committee, which is comprised of senior level staff from the different agencies is to resolve any issues and to make sure that there is consensus among the different groups. It also helps ensure a link to the decision makers within the various agencies.

Another approach we used to help ensure the involvement of all the appropriate groups was a teaming or partnering session. This session involved representatives from all the agencies and the consultants. It provided the opportunity to identify and discuss potential issues and concerns, to initiate the development of the communications architecture, and to discuss the objectives of different groups.

The teaming session also helped ensure the development of a manageable project scope. Reaching agreement on the key project objectives was an important part of the process. Ensuring that all the groups were kept informed and updated on the status of the project and that their comments and concerns were being addressed were also part of the process.

The development of the communications matrix was challenging. This matrix provides names and phone numbers of the key representatives at all the different agencies involved in the project. The teaming charter and the mission statement were signed and agreed to by everyone at the session. The project itself is split into four different phases. These are the development of the system requirements, the system design, software development, and implementation. We are now working on the systems requirements. This phase is identifying existing systems, data sources, and infrastructures that can be used to support the North Seattle ATMS project. New data sources expected to come on-line within the next few months are also being examined for possible incorporation into the project. Developing a priority list of all the base user requirements is a major component of this phase.

The design phase will take the information from the systems requirement phase, refine it, and develop a communications architecture. This phase includes the development of the hardware and software requirements. At both ends of the first two phases, a reality check is being made to compare the budget and the schedule required to implement the base requirements against the negotiated schedule. This comparison is being made to ensure that adequate resources and time are available to implement the system.

The software development phase will then be initiated. This phase includes developing the functional description for the system, as well as the coding and documentation of the system. The final stage is the implementation of the system, which is projected to begin in early 1996. An evaluation of the North Seattle ATMS project will be conducted by the Washington State Transportation Center at the University of Washington. This evaluation will focus on the impact of coordinated control on facility performance and safety, the success of the system software in facilitating integration, institutional issues that influence the development of the system, acceptance of the system by isolated system operators, and examining the use of ITS for data collection.

Implementation of the North Seattle ATMS project is scheduled to start early next year. A two year development schedule is planned. This is an aggressive, but manageable schedule for a project of this type.

As I noted, a number of major activities have been completed. A report detailing the geographical limits of the project has been completed. An inventory of existing signal controllers, surveillance data bases, and other equipment and communication infrastructure in the project area is almost complete. A draft report on the proposed system architecture has been developed. This report addresses the data collection, processing, storage, and retrieval mechanisms of the system. A report is also expected by mid-June on the proposed control strategies. The types of strategies will include time-of-day, traffic responsive, and integrated arterial-freeway control.

In conclusions, I would like to highlight four major points about the North Seattle ATMS project. First, like other ATMS projects, this effort is very challenging both from a technical and an institutional perspective. Second, the Seattle experience confirms the need to move slowly and logically in the development of ATMS. Making sure the project objectives are clearly articulated, are realistic, and are reexamined periodically is critical. Third, it is important to have regional vision, especially in considering the communications architecture. Finally, the most important point is to establish a team concept. Ensuring that all groups are involved and support the concept is critical to the success of an ATMS project.

PLENARY SESSION-ITMS Issues

Raj Ghaman, Federal Highway Administration-Presiding

Roles and Responsibilities

Larry Heit, Ohio Department of Transportation

The Advanced Regional Traffic Interactive Management Information System (ARTIMIS) is currently under development in the Cincinnati metropolitan area. The system will cover the bi-state area which includes Cincinnati, Ohio, Covington, Kentucky, and surrounding suburbs.

ARTIMIS represents the coordinated efforts of the Kentucky Transportation Council, the Ohio Department of Transportation, the FHWA, OKI-which is the MPO for the area-and the City of Cincinnati. TRW is the major contractor for the system, which is currently in development, with full deployment scheduled for October 1996.

As Raj mentioned, one of the challenges of this project has been the involvement of multiple jurisdictions and two states. Ohio is a home rule state, which means that the cities have total control over the roadways in their jurisdictions, including the Interstate system. The municipalities provide all police, fire, and EMS services on these facilities. There are some 20 jurisdictions and 80 agencies in the area covered by ARTIMIS.

The goals of ARTIMIS are to improve air quality levels, enhance overall safety, and decrease travel times. To do this the system will ultimately provide pre-trip travel information, in-vehicle navigation capabilities, in-route guidance, traffic and congestion management, and other services.

I-75 and I-71 form the main north-south freeways in the area. ARTIMIS will encompass 88 miles of the freeway system. Approximately 75 percent of the project is in Ohio and 25 percent is in Kentucky The system involves 825 loop detectors, 60 wide beam radar units, 26 video detectors, 50 closed circuit television cameras, 43 changeable message signs, five highway service patrols, HAR, and telephones for traffic information queries. Communication will be by fiber optic cable and the control center will be located in downtown Cincinnati.

The development of the system was initiated by OKI, partly in response to the designation of the metropolitan area as an air-quality non-attainment area. A committee was formed by the two states to develop a plan for the system. The result of this effort was the ***OKI ARTIMIS Implementation Prospectus*** published in 1993.

A Policy Committee, comprised of representatives from the two state departments of transportation and OKI, was established to oversee the development of a request for proposal (RFP) for consultant services, the selection of a consultant team, and the deployment of the system. A Technical Committee was also formed. This committee includes members from both states, OKI, the City of Cincinnati, and the FHWA. There are also four subcommittees, including one on software which I head. Kentucky assumed the lead on the project, in part because of more flexible procedures in the consultant selection process.

The development of the RFP was a major challenge. I was concerned about the lack of detail concerning the system software. There was only one sentence in the initial RFP concerning software. After discussions with many people and extensive reading, we were able to expand the software specifications significantly. This was especially important since a lump sum contract was going to be awarded to the selected consultant. I think it is very important to ensure that the software specifications are clearly spelled out, since the software is the core of the system.

Based on our experience, I would also stress the critical need to communicate and coordinate with local jurisdictions and agencies. Bringing them into the process early is important. This should include listening to their needs and problems and showing them how ITMS will help them do their job better.

I hope to be able to report more on the status of ARTIMIS at the next Symposium. Further, we would welcome the opportunity to host a future ITMS Symposium in Cincinnati.

Legal and Procurement

Cindy Elliot, ITS Joint Program Office U.S. Department of Transportation

It is a pleasure to have the opportunity to talk with you today. Others have mentioned the importance of the early invovlement of all groups in the ITMS planning process. I would strongly encourage that attorneys be part of this group. Attorneys can help with issues that may cause problems later in the development process. Identifying and addressing potential issues early can help reduce unanticipated delays in the implementation of ITMS.

The U.S. Department of Transportation's ITS institutional issues program is focusing on more than just legal issues. Environmental and social issues, mainstreaming ITS and the planning process, inter jurisdictional concerns, privacy issues, and liability issues represent just some of the other areas being examined. An initial scoping of the major issues in all these areas has been completed, and we are now focusing on practical applications that will assist in the deployment of ITS. ***This*** effort is not focusing on a "one size fits all approach." Rather, we are looking at the experiences from projects around the country, including those highlighted at this Symposium, and identifying approaches which appear to work.

Two projects underway are focused on this kind of experience sharing. They also involve a legal research component. One of the projects is examining shared resource ITS activities. The other effort is examining innovative contracting procedures.

One of the issues being examined is the effectiveness of different contract instruments for various ITMS deployments. Most people are familiar with fixed-price and cost reimbursement contracts, as these approaches are commonly used with all types of projects. More innovative contracting mechanisms include design/build, build-transfer-operate, build-operate-transfer, and cooperative agreements. These approaches may provide greater value to agencies on some types of ITS projects.

Some agencies have experience with design/build approaches, while others are considering it. Build-transfer-operate is commonly referred to as a turnkey approach, while build-operate-transfer is known as the privatization approach. Cooperative agreements have been used with some of the ITS Operational Tests. Concerns have been raised by the private sector on whether this approach is competitive enough for deployment, however.

We are also examining the effectiveness of contract award methods for different ITMS procurements. You are all well aware of the problems with low-bid procedures for the procurement of high technology systems and projects. These problems have sometimes resulted in the separation of the design and the construction phases of a project. Better value may be obtained from the contractor, however, if these two phases can be combined.

There appears to be a good deal of interest on the part of public agencies in considering performance criteria in procurements. Although public agencies have a good understanding of the goals and functional requirements of a system, they may need assistance in developing the technical specifications. The private sector may be looked at for this expertise. There is concern among private firms with thii approach, however, which has resulted in a good deal of litigation. Functional and performance requirements are not easy to develop and the private sector often complains that public agencies do not do a good job of outlining what they want.

A number of private companies have identified numerous ideas for partnerships with public agencies. This approach, known as private initiatives or sole source awards, has not been used widely, however. States vary in their ability to use sole source contracts. Staged procurement is another approach being considered in some areas. One concern among the private sector with this approach is that it lacks predictability. There is no guarantee with this approach that a company making significant investments in the development of a proposal and the early phases of a project, will be awarded later phases of the contract.

One real challenge in developing public/private partnerships is determining the value of the different elements. These might include the value of the public investment in the cost sharing elements such as goods and services, the value of the risk being assumed by the public sector, and the research and development costs assumed by the private sector. There is also a good deal of controversy over the treatment of intangible assets and how system integration is paid for.

A number of benefits may be realized through combined or coordinated procurements. Many of these are well known. The ability to increase the purchasing and negotiating leverage with vendors may be one of the more important of these benefits.

Other speakers have touched on some of the administrative difficulties of different contracting approaches. Many of the more innovative approaches are subject to political and administrative changes. New approvals may be needed with new elected officials or administrative personnel. Further, joint efforts may be very time consuming. Private sector groups have expressed concerns with the time it takes to address the requirements of numerous public agencies. There is also an ongoing need to ensure the compatibility of the technology being used by the different agencies.

As I noted, a major part of the institutional program in this area is identifying good experiences and case studies. We are also developing training material that can be used by a wide range of groups. Some of the initial training efforts are focusing on the use of flexible procurement regulations and the development of technical specifications. I would welcome any ideas you might have on training needs and training approaches in this area.

There has been a good deal of interest in shared resource projects by state departments of transportation. There are a number of legal and political issues associated with shared resource projects, however. In addition, telecommunication agencies are very concerned about groups that create their own systems rather than taking advantage of capacity in existing telecommunication systems. This issue has created a good deal of political interest and Congress is considering possible legislation in this area.

Another shared resource issue relates to if a utility accommodation policy provides the authority to use public right-of-way for telecommunications. Some areas have found many telecommunication companies already have established access and do not have any interest in the public sector projects.

One of the most important issues with shared resources is the lack of public sector authority to receive or earmark compensation from public/private projects. Many states are simply not interested in such arrangements. This issue has wider ramifications for public/private partnerships in many areas.

There are a number of financial issues that also need to be addressed. One of the more important of these concerns relates to how public resources are valued. A variety of techniques have been used to assess the value of public resources on projects, but no one best approach has emerged. Some examples of methods used to date include competitive auction, cost of the next best alternative, and needs-based compensation.

Project structure issues may also need to be examined. The type of consideration is one of these issues. When valuing any public resource, it is important to consider not only current needs, but also future needs. For example, there have been cases where the full long-term value of a right-of-way was not adequately consider in the valuation process.

There are a number of other issues that should be examined to ensure that the best agreement is realized for all groups. These include concerns related to relocation, system modification, geographic and social equity, liability, intellectual property rights, and the potential for one community or area to be favored.

Finally, privacy is a major concern with ITS among many groups, especially the public. We need to do a better job of explaining ITS and the benefits of ITS projects to the public. One lawyer has said that "ITS is infested with nearly impenetrable and constantly changing acronyms, not to mention obscure technical language which is frequently understandable only to the most intrepid technofile."

On the other hand, the public seems to have grasped the privacy issues associated with ITS. Even the ***New York Times*** has questioned the privacy implications of ITS. This is an area we need to be extremely sensitive toward. We have sponsored a number of studies on the privacy issue, and there are some excellent reports available on how **to** ensure privacy safeguards. There are three major ways to address the privacy issue. These include technical strategies, the development and use of industry fair information principles, and federal or state statutes. All three approaches will need to be used to ensure privacy safeguards with ITS.

Thank you for your kind attention. There are a number of other issues I could discuss, but I will hold those for the workshop sessions.

System Integration Issues
Philip Tarnoff, Faradyne Systems, Inc.

My presentation, which will focus on system integration issues, is intended to help set the stage for more detailed discussions in the workshop sessions. Since I will be addressing problems associated with system integration, many of my comments will be negative.

It is important to remember, however, that there have been a number of significant successes with system integration in traffic management. Addressing issues such as schedule overruns, cost overruns, technical difficulties, and other concerns will be important for the future deployment of ITMS and ITS.

Many of the problems with system integration are not new. In fact, this presentation probably could have been given 25 years ago. Little progress has been made in addressing some of these problems over the years. One of the reasons for this lack of progress is that ITS is an outgrowth of the highway system. As a result, we are suffering from many of the safeguards and constraints that have been placed on highway construction over the years. The process used for building concrete freeways is not the same process that is needed to design and develop complex electronic, computer-based, and comunications-based systems. More focus is needed on examining legal and policy issues associated with contracting and system design, development, and operation.

System integration is the process of combining software elements, hardware elements, or both into an overall system. As such, system integration activities must be part of the ITMS development process from the very beginning. Early involvement in the planning process, which should continue through design and implementation, will help address many potential problems with system integration.

System integration is not an easy process. Although it is easy to draw two boxes on a piece of paper and connect them with a line labeled RS232, it takes a long period of time to actually accomplish the link between the two.

System integration is extremely important given the complex systems that are being developed in ITS. Since ITMS involves public safety, the reliability of the systems is critical. It is also important to remember that all groups-from both the public and the private sectors-share the responsibility to develop reliable systems on schedule and within budget.

There are a number of reasons why issues still arise in system integration, even when all parties are committed to the process. First, ITMS are complex, encompassing hardware and software with both wide area networks (WAN) and local area networks (LAN), multiprocessor environments, large geographic coverage, unpredictable environments, and unpredictable functional and geographic expansion.

A number of issues often cause problems during system integration. First, public agencies may not be aware of either the elements or the conditions of the existing infrastructure. This includes the elements they are directly responsible for, as well as the infrastructure of other groups. This can result in numerous surprises when a system is being implemented.

Second, agencies may require specific software designs or equipment. Custom designs, which are very expensive and frequently not needed, may be requested. At one time, we thought it might be possible to develop standardized software. Even though the MIST system mentioned this morning allows for this, none of the approximately 30 installations of MIST have been the same due to special requirements, unique reporting features, and other local desires. These special requirements can significantly increase the cost of a software system.

Third, the distribution of responsibilities can often cause problems in the design and development of a system. The responsibility for the success of a system usually does not rest with just one agency. Rather, success is often shared between the public sector agencies and the private sector groups involved in the system design and development. In addition, coordination must occur not only among these groups, but also among the numerous departments within each of these groups.

Current attempts to solve system integration issues often involve increasing funding levels. New ways are needed to address and resolve these concerns. Identifying new techniques and approaches would be a good topic for consideration in the workshop sessions.

No discussion of system integration issues would be complete without a discussion of the two commonly used contracting approaches-systems manager and the consultant/contractor. In the systems manager process, a single company is responsible for the software design and development, and system integration. The public agency then procures the hardware, software, and construction services using a low bid procurement process. The consultant/contractor method has traditionally been used to design and build highway projects. Under this approach, a consultant designs the system and then the agency procures a turnkey installation using this design.

Neither approach is perfect, and there are potential problems associated with each. Possible issues with the systems manager method include no single point of responsibility, lack of control over system interfaces, no guarantee of mature technology, and no guarantee of prior experience. This technique may also force custom tailoring of software and provides little control over schedules and inspection. The consultant/contractor approach may discourage adequate budgets and schedules for system integration. Other problems with this approach include the fact that the contractor has to implement the design produced by another consultant, the lead contractor-which is usually an electrical firm-rarely considers system integration issues, and the system integrator may have little control over schedules and reviewcycles.

In conclusion, I would like **to** identify a few elements for successful system integration. First, a single point of responsibility is critical. Second, it is important to provide well defined system interfaces. Third, I would strongly recommend system testing at every step. Although this will increase costs, the end results will be better and it may save money in the long run by avoiding more expensive problems. Finally, I would suggest maximizing the use of mature technologies, rather than requiring special interest components.

Operations and Maintenance

Ed Rowe, Gardner-Rowe Systems, Inc.

So far at this Symposium we have primarily heard de good news about ITMS. We have heard how ITMS is going to provide public agencies with the means to better manage traffic and to provide useful services to the traveling public. We have been told how this will be accomplished through a combination of advanced technologies involving networked computers, complex software, fiber optic and microwave communication systems, detectors on of all of our highways, closed circuit television, changeable message signs, HAR, and other approaches. We have heard how we will be able to monitor traffic on our street system and get this information out to the public.

We have ‘not heard too much about the bad news associated with these systems, however. The bad news is that most of this new high-technology equipment and software will be the responsibility of state and local agencies to operate and maintain. This is a quantum leap in the amount and complexity of equipment these agencies will be responsible for. If we are not careful, this wonderful dream could turn into our worst nightmare. This could happen if currently inadequate resources are overwhelmed by the demands of operations and maintenance of this system.

Fortunately, operations and maintenance of ITS projects was recognized as a major problem facing public agencies several years ago. I will briefly cover the positive actions that can be taken to address the complex issues associated with operating and maintainmg ITMS and other ITS technologies. After providing a brief background, I will highlight issues in the four general areas of implementation, staffing and training, institutional, and funding.

A 1990 study conducted by the FHWA Office of Program Review, which included a survey of 24 representative traffic control systems deployed by state and local agencies, first identified the problems associated with operations and maintenance. This study found that 21 of the 24 systems did not meet minimum standards of performance due to inadequate operations and maintenance. These findings raised concerns about plans for a national ITS program. If state and local agencies were not able to operate and maintain existing systems, what would happen with more complex projects using more sophisticated technologies.

The FHWA established an internal Task Force to investigate actions that could be taken to improve the situation. This Task Force examined the issues and made a number of recommendations on ways to improve the situation. The FHWA also convened an Expert Panel comprised of representatives from state and local agencies, a consulting firm, and a university. This Expert Panel completed a report in 1993 which included 34 recommendations. The FHWA developed an Action Plan incorporating the highest priority recommendations of the Expert Panel.

The General Accounting Office (GAO) also conducted a review of the problems preventing state and local agencies from realizing the benefits from traffic control systems. The GAO submitted a report on their findings to Congress in March of 1994. The GAO report reinforced the conclusions of the FHWA reports and recommended several specific actions.

The FHWA contracted with the Institute of Transportation Engineers (ITE) to address a number of the identified ITMS operations and maintenance issues. ITE undertook a number of activities including mail and telephone surveys of state and local agencies and focus groups. Three reports based on these surveys are nearing completion.

ITE also sponsored a national conference on ***Operating and Maintaining Traffic Control Systems*** and an educational foundation seminar. Further, ITE established a national clearing house for the distribution of information on traffic control systems and a toll free hot line. Finally, ITE's ITS Council established a task force to deal with operations and maintenance activities.

I would like to now turn to a discussion of the four issue areas, starting with implementation problems. In my experience, consideration of operations and maintenance issues are often left to the end of a design phase of the project. I would like to suggest that these issues should be addressed at the beginning of a project, rather than the end. To accomplish this objective, personnel responsible for operations and maintenance should be involved early and throughout the system design phase. Trade-off analyses of hardware and software design options should include the long-term life-cycle effects on operations and maintenance costs and staffing requirements. More research is needed in this area, but examining the life-cycle costs of ITMS will be critical to providing adequate funding for operations and maintenance.

Design standards are also very important. To the extent possible, uniform design standards for hardware, software, communications, and installation should be considered. This will help reduce the complexity of the integrated system, simplify hardware interfaces, and reduce long-term operations and maintenance problems.

Potential issues associated with system procurement have been described by other speakers. There is general agreement that the low-bid process is not adequate for procurement of advanced technologies. The low-bid process can also cause future operations and maintenance problems. The FHWA appears to be moving faster on addressing this issue than many states and local governments.

Investments in construction inspection and acceptance testing will have big payoffs. These should be conducted to help avoid potential problems related to faulty construction, as well as hardware and software development mistakes.

Finally, hardware and software documentation is an important but often overlooked issue. It has been my experience that these products are usually left to the end of the project when funding is running low. Additional up-front investments in hardware and software documentation can result in significant long-term benefits to operations and maintenance.

I think most agencies are aware of staffing and training issues and the fact that they will need additional personnel with new skills to maintain and operate ITMS. Staff will be needed with expertise in electrical engineering, computer science, and digital fields. These individuals will need to be compensated at appropriate levels and be provided career paths if we hope to keep them. There is a shortage of individuals with these skills today, and there is a high demand for people with expertise in these areas. Training is another activity that often gets left to the end of the development process. Even at this point, training may be nothing more than a one week course. Training should begin at the start of a project, not at the end. Ideally, the core staff should have been hired and basic training performed during system installation. This is an excellent time for "over-the-shoulder" training, with the core staff working alongside the consultants. A second phase of training consists of the prime contractor and subcontractors providing agency staff with classroom and "hands on" training in all essential operations and maintenance functions prior to system turn-on. Finally, an ongoing training program should take advantage of the large number of courses available through universities and other groups. Many local agencies may not be aware of all the opportunities offered by these groups.

The possibility of contracting operations and maintenance functions deserves further consideration. Managers should take a serious look at this approach. Contracting for operations and maintenance could be a long-term approach or it could be used as a short-term bridge until local staff are adequately trained. The INFORM system in Long Island, New York, is a good example of this type of long-term contracting arrangement for operations and maintenance of ITMS.

A number of institutional issues must also be addressed in the operations and maintenance of ITMS. The active involvement of multiple groups will be critical to the success of individual projects. Agreements regarding operations and maintenance responsibilities and level of effort should be established early in the design process.

Establishing policies and procedures for the coordination of inter-jurisdictional operations should also occur early in the development process. These procedures should address issues such as incident management, congestion management, diversion of traffic from freeways to city streets, changeable message signs, ramp metering and closure policies, and coordination of traffic signals at jurisdictional boundaries. ITMS also provides the opportunity for joint maintenance of equipment among agencies. Smaller public organizations could especially benefit through joint maintenance activities with larger agencies and jurisdictions.

ITS also provides enhanced opportunities for technology transfer. The closer public agency relationships fostered by ITMS projects should facilitate more frequent sharing of this valuable technical information among all participating agencies.

Finally, ITMS may require changes in the organizational structures of many agencies. Operations and maintenance are typically in separate departments in most agencies today. Each has their own set of priorities, and coordination between the two groups may be lacking. ITMS will require closer cooperation and coordination between operation and maintenance departments.

The final issue is funding. This is clearly a long-term problem. The establishment of an adequate and dependable long term funding source for ITMS projects is a major challenge for state and local agencies. This problem has historical roots in the way highway projects have been funded. Funds for design and implementation come from one budgetary source, while funds for operations and maintenance come from another source. This separation in funding sources has frequently resulted in ample funds for project implementation and inadequate funds for critical operations and maintenance functions.

Certain provisions of the ISTEA go part of the way toward addressing the problem of funding operations and maintenance. Two years of startup costs are allowed for projects funded under the National Highway System. Under provisions of the Surface Transportation Program, ITMS operational costs can be funded indefinitely. The Congestion Mitigation and Air Quality Program (CMAQ) allows funding for two years of operating costs.

These provisions of ISTEA are certainly a move in the right direction. Every effort should be made, however, to revise this legislation to allow complete flexibility by state and local agencies in the allocation of funds. Funding at the state and local levels also needs to change. State and local agencies cannot rely entirely on the federal funds for operations and maintenance of ITMS projects. At a minimum, matching funds will be required. To the extent that any restrictions on the use of state gas tax funds for operations and maintenance of ITMS by local agencies exist, they should be removed.

In conclusion, there are a number of positive actions that can be taken to address these issues. Solutions are available to the issues associated with adequately operating and maintaining ITMS. All that is needed is the will to change. Thank you.

PLENARY SESSION-Workshop Results

Adolf May, University of California, Berkeley-Presiding

Roles and Responsibilities

Jonathan McDade, Federal Highway Administration

The workshop session on roles and responsibilities began with a discussion of what was meant by an integrated transportation management system. There was agreement that the context of ITMS, as defined in the Symposium, is operations oriented. There was also an extensive discussion regarding the relationship of ITMS to the management systems mandated in the ISTEA and to the overall transportation planning process. Concerns were expressed that too many jurisdictions and agencies are vertically oriented and may lack the horizontal integration needed to support ITMS. The focus of the workshop then turned to identifying issues related to the roles and responsibilities of the various players involved in ITMS from an operational perspective.

The following issues and opportunities **were** identified for the seven major groups involved in ITMS-the federal government, state governments, local governments, metropolitan planning organizations (MPOs), emergency services, transit agencies, and private sector groups.

Federal Government

- Federal agencies provide advice and guidance on how ITMS, ITS, the ISTEA management systems, and major investments studies all fit together. An overall vision is needed from the federal government to help promote coordination among these different elements.

- The role of the federal government in enforcing the provisions of the ISTEA and other legislation and in providing guidance and direction was discussed.

- Federal agencies support funding needs.

- Federal agencies support education and training needs.

- Federal agencies support documentation and communication of the benefits of ITMS.

- Federal agencies support ITMS research.

- A national goal, vision, and picture of ITMS is needed from the federal government.

- Federal agencies support the development of national standards.

State Government

- State agencies support and help fund local ITMS initiatives.

- State governments provide the legislative and policy support for ITMS.

- State agencies support statewide and regional ITMS needs and requirements.

- State agencies support education and training needs.

- State agencies support operations and maintenance needs.

- State agencies provide feedback to FHWA and FTA on ITMS issues, opportunities, and benefits.

- State agencies provide review authority of ITMS actions.

- State agencies provide a legal environment that supports ITMS procurements.

- State agencies support multi-agency coalitions and participate in cooperative efforts with local agencies.

- State agencies support private sector collaborations and partnerships.

- State agencies support the development of standards and databases.

- The impacts of internal state agency organizational structures on ITMS should be explored.

Local Government

- Local agencies help ensure that local needs are addressed in ITMS.

- Local agencies need to show a willingness to change to support ITMS .

- Consistency in local budgets and resources to support ITMS is needed.

- The level of control-shared versus mandated-needs to be examined as it relates to local agencies.

- Land use and transportation impacts needs to be explored, as these are critical factors at the local level.

- There is a need to explain the benefits of ITMS at the local level.

- There appears to be a lack of understanding about ITMS by many elected officials. Educational programs are needed to explain ITMS to local officials and the public.

- Social and cultural constraints related to ITMS need to be explored.

- Local governments need to take responsibility for local actions.

- Modeling capabilities for estimating the benefits of ITMS need to be developed.

- The impacts of local agency downsizing on ITMS need to be explored.

Metropolitan Planning Organization

- The authority of MPOs related to ITMS was discussed.

- Enhanced communications with MPOs is needed.

- The responsibility of MPOs in ITMS implementation was discussed, especially the fact that MPOs are non-operating agencies and that ITMS is an operational system.

- There is a need to clearly define the MPO role in ITMS.

- MPOs can play a key role to help facilitate the development and operation of ITMS.

- MPOs can assist in coordinating land use and transportation.

- MPOs have a key role to play in air quality conformity planning.

- There is a need for improved modeling tools.

- There is a need for MPOs to develop a vision of the future transportation system and how ITMS fits into this vision.

Police, Fire, and Emergency Services

- The degree of information control required by these groups needs to be explored.

- There is a need for all groups to agree on standard procedures to be used at the scene of an incident.

- There is a need to explore the privacy issues that emerge with the involvement of these groups.

- There is a need to examine authority and turf issues that may emerge with the involvement of these groups.

- The level of cooperation among these groups and between these groups and other agencies needs to be enhanced.

- The special mission of these groups to protect the public welfare and safety needs to be considered.

- The potential liability issues with the involvement of these groups in ITMS needs to be explored.

- The need for possible legislation to allow these groups to be involved in ITMS should be explored.

- Communication is key with these groups.

- Issues related to safety and efficiency versus enforcement need to be explored.

Transit

- Transit is not now a part of the ITMS process in many areas. Exploring ways to increase transit involvement in planning, designing, and operating ITMS is needed.

- The number of transit properties, which may have different priorities, may be a problem with ITMS in some areas.

- There is a need for flexibility among transit agencies and all groups in accepting integrated solutions.

- The benefits of ITMS for transit operators need to be explored.

- There is a need to involve transit agency representatives early in the ITMS planning process.

- Issues related to equity and social responsibilities versus mobility need to be explored.

- The impact of federal requirements, such as the Americans with Disabilities Act (ADA), on ITMS need to be explored.

- Transit often feels left out of ITMS and ITS. Techniques for encouraging greater participation from transit representatives need to be explored.

- The potential impacts of heavy transit vehicles on streets and other infrastructure elements need to be explored.

- The separate sources of federal funding for different modes can be a problem in the development and operation of ITMS.

- Possible concerns over the level of operations and maintenance subsidies need to be explored.

Private Sector

- The potential for profits from private sector involvement in ITMS needs to be explored.

- The real expertise of different groups needs to be considered in the development and operation of ITMS.

- Private sector representatives can act as educators in advancing ITMS .

- Private businesses can play an important role in supporting ITMS partnerships and collaborations.

- There is a need to move toward more openness in the ITMS planning and design process.

- There is a need to better define the possible roles of industry and private sector groups involved in ITMS.

- There is a need to recognize long run versus short run profits with ITMS.

- Liability issues related to the development and operation of ITMS need to be examined.

- Private sector representatives can provide needed leadership in ITMS.

- Quantifying the benefits from ITMS to private industry groups is needed.

- Private sector groups can help support technology development in ITMS.

- Private businesses may also be involved through the trip reduction potentials of ITMS.

Following this discussion, a list of issues related to the roles and responsibilities of the different groups involved in ITMS was developed. Each member of the workshop identified their five top issues. The following five issues emerged as the most critical for helping advance ITMS.

- Defining the MPO role and authority in ITMS.

- Promoting transit as a full player in the ITMS process.

- Encouraging the development of federal guidance on ITMS and other ITS program elements.

- Enhancing funding support for ITMS.

- Communicate the benefits of ITMS at the local level.

Other issues such as operations and maintenance and public safety agency procedures during incidents were also rated highly. Specific actions that could be taken to address each issue were identified by the workshop participants. These are summarized next.

Issue-Defining the MPO role and authority in ITMS.

Actions

- Develop recommendations for the next federal transportation re-authorization bill.

- Encourage dialogue among federal, state, local governments, and MPOs.

- Discuss the role of MPOs in ITMS at other conferences.

- Disseminate summaries from certification reviews on MPO performance from a national perspective.

- Support research on regional modeling and technical tools.

Issue-Promote transit as a full player in the ITMS process.

Actions

- Work with the American Public Transit Association (APTA) to encourage greater transit involvement in ITMS.

- Support the development of information on the benefits of ITMS to transit industry aud communicate this to transit agencies and operators.

- Communicate the benefits of transit involvement in ITMS to traffic engineers.

- Add a transit representative to the TRB ITMS Symposium Planning Committee.

- Add a transit representative to the TRB ITMS Subcommittee.

- Encourage greater transit involvement in the Institute of Transportation Engineers (ITE) ITS Council.

- Encourage greater transit involvement in congestion pricing studies.

- Involve transit agency representatives in establishing ITS ***America*** state chapters.

Issue-Encourage the development of federal guidance on ITMS and other ITS programs.

- Clarify the relationship of ITMS, the ISTEA management systems, and MIS within the planning and operations framework.

- Encourage the development of information on the measurable benefits of ITMS, including case studies and best practice examples.

- Support the development of information on ITMS success stories, experiences on what works, and best practices.

Issue-Enhancing funding support for ITMS.

Action

- Support a study to determine if funding mechanisms at all levels support ITMS objectives.

Issue-Communicate the benefits of ITMS at the local level.

Actions

- Support a task force targeted to providing information on ITMS to local communities.

- Focus communication efforts on local groups, such as chambers of commerce, local officials, businesses, and other organizations.

- Communicate the benefits of integrating existing systems and developing ITMS to local organizations using focus groups and other market research and marketing techniques.

Legal and Procurement
Frank Dolan, Monroe County, New York

This workshop started with the identification of the legal and procurement issues associated with the design, development, and operation of ITMS. A total of 30 issues were identified during the initial discussion. The workshop participants then reviewed these issues for common themes. The five general areas of contract issues, legislativeneeds, operational and privacy concerns, innovative financing, and liability issues emerged from this discussion. The following issues and action statements were developed to help define the major concerns within each of these five areas.

Issue-Contracts

- Current methods of contract award are inappropriate for procuring advanced technology equipment and services. For example, pre-qualification requirements may preclude certain companies from being the prime contractor, and state and federal regulations often prohibit sole source contracts. Low-bid requirements are often not the best approach for high technology procurements.

- Burdensome requirements are often placed on contractors in ITMS. These may include financial disclosure requirements, which may preclude certain firms from participating in ITMS, and proprietary software issues.

- The multi-party contracts needed in ITMS introduce new complexities in the development and operations of systems.

Action

- Develop a package of effective contracting recommendations and actively promote their use by contracting agencies. The Legal Issues Committee of ***ITS America*** is appropriate take the lead on this effort with input from the different user groups.

Issue-Legislative

- There is a need for more flexible legislation to encourage greater opportunity and authority for partnering at both the state and the federal level.

Action

- Develop recommendations for operational policies addressing privacy issues associated with ITMS. ITS *America* with input from AASHTO, ITE, and other groups are appropriate to undertake this effort.

Issue-Operational and Privacy

- Policy and legal guidance is needed on what information is in the public domain, what information can and should be collected, and what information can and should be released.

Action

- Develop model legislation and encourage its use by states. The states are appropriate to take the lead on this with assistance from ***ITS America, the American*** Association of State Highways and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and other groups.

Issue-Innovative Financing

- Information and procedures are needed for determining the value of public resources and public infrastructure elements. Information and guidelines are also needed on how to use ITMS-generated revenues to operate, maintain, and expand the system.

Action

- Support the development of guidelines for determining the value of public resources and public infrastructure elements. This could include the development of recommendations for channeling revenues to support ITMS operation, maintenance, and expansion. AASHTO is the appropriate group to take the lead in this effort with input from the states.

Issue-Liability

- Clarification is needed on potential liability concerns and how that liability can be allocated among the groups involved in ITMS.

Action

- Support the identification of the potential liabilities associated with ITMS and recommend methods for fair allocation of potential liability among the groups involved. The states are the logical entity to take the lead in this effort with federal guidance and input from ***ITS America,*** AASHTO, and other groups.

System Integration

Donald Dey, City of Menlo Park, California

This workshop focused on a discussion of the system integration issues associated with ITMS. To help frame the discussion, a hypothetical multi-agency ITMS project was proposed with participants assuming the roles of staff from the different agencies involved. The project management team for the ITMS consisted of representatives from a state department of transportation, a transit agency, a city, an air quality control district, a police department, and the private sector. The following five key issues and recommended actions were identified through this process.

Issue-The term system integration needs to be defined for the team.

Action

- The team should identify the three levels of system integration. These are institutional integration, procedural integration, and technical integration. The process of defining each of these levels will provide a forum that allows all agencies to identify their needs and wants.

Issue-Identify the qualities that a system integrator should possess.

Action

- For the institutional issues, the team should establish an ongoing coordination committee. For the technical and procedural integration, a private or public agency should be sought that has the horizontal capabilities to understand every agency's needs and desires.

Issue-How does the team minimize the life-cycle costs associated with ITMS?

Action

- The team should develop a requirements identification process that highlights each agency's goals and needs. The team should select appropriate industry standards for hardware and software components to minimize life-cycle costs of implementation, operations, maintenance, and staffing.

Issue-How will the system guidelines and standards address rapidly evolving technologies?

Action

- The system design guidelines and standards should be developed to allow continuous response to the availability of new technologies, with a focus on common level system elements.

The workshop participants then discussed who should implement the five recommendations. There was agreement that the lead agency or system integrator agency should be the organization with the most appropriate resources. The lead agency may vary from area to area. In many cases, the state department of transportation will be the appropriate agency. This may not always be the case, however, and other agencies or a new organization may be the logical lead group in some areas.

Operations and Maintenance

Joe McDermott, Illinois Department of Transportation, and ***Ed Rowe, Gardner-Rowe Systems, Inc.***

Participants in **this** workshop discussed the operation and maintenance needs of ITMS. Four general issue categories were identified to help focus this discussion. These were implementation, staffing and training, institutional, and funding. The role of the private sector in operations and maintenance was also discussed. The major issues identified in each of the four categories are summarized next.

Implementation Issues

- Operations and maintenance staff from the different agencies need to be included early in the ITMS planning and design process.

- Life-cycle support should focus on the quality of the installation, not quantity. There is also a need to define the life-cycle length associated with ITMS components.

- Concerns were raised as to how much of an issue an ITMS manager should make about operations and maintenance funding in promoting a project. There was agreement that the estimates should be realistic and that they should be openly addressed early in the process so that they do not become a new issue later.

- There is a need to get private sector personnel and firms involved in the initial preliminary design phase of ITMS.

- Enhanced coordination among jurisdictions concerning ongoing operations and maintenance is needed to ensure that all groups are involved and committed and that any necessary agreements are in place.

- The issue of a possible partnership with the media and the role they should play was discussed. Concerns raised focused on including media representatives within the control centers, what agreements need to be in place with the media to provide and share information, and possible liability issues concerning video transmissions.

. The potential of partnerships with wrecker services for incident response was discussed. Different contracting procedures were identified and possible liability issues were outlined.

- Government/media/private partnerships must also include accountabilities to define how any partner may drop out without severe burden on others.

- The role and authority of the FHWA in requiring operation and implementation plans was discussed. The current regulations and standards for FHWA involvement in monitoring operational plan was also discussed. It was noted that FHWA requirements can be used by agencies to obtain support from decision makers for operations and maintenance funding.

Staffing and Training Issues

- A skill inventory of personnel needs should be conducted during the design phase, prior to implementation.

- ITMS may provide the impetus to make organizational changes and to add efficiencies within agencies. Head counting versus right-sizing was discussed. Participants noted the importance of remembering that the Interstate system has been built and that there is a shift from design and construction to systems management.

- Operations and maintenance often require staffing beyond the normal 40-hour work week. 24-hour operations are usually required. It takes five people to staff one position when 24 hour-a-day, 7 day-a-week operations are required.

- San Antonio is exploring the possibility of connecting personnel at home to respond remotely when the operations center is not staffed. The Atlanta system is being designed to allow the control center to take control of several sub-regional centers during off hours if necessary.

- Exploring possible opportunities to take advantage of emergency services technologies and organizations to build upon and to minimize operations staff were discussed.

- Problems with finding qualified staff were discussed, particularly since non-traditional disciplines may be needed for ITMS.

- The fact that technical skills, as well as personal skills, are needed in operations and maintenance was noted by participants.

- There was agreement that courtesy service patrols are the best public relations program of many state departments of transportation. Motorist assistance patrols may be counted as part of the operating staff, however, which can be a drawback.

- The point was made that agency staff resources are still needed for oversight even if work is contracted out.

- Currently, politicians are very conscious of reducing staff levels in many agencies. This often forces contracting out for operations and maintenance functions.

- Each ITMS is unique, so staff levels may vary. Liability issues may emerge if staffing is not adequate for an emergency situation, however. The suggestion was made to establish standards based on functions for staffing needs. These might include the hours of operation for the system or other functional standards.

- Exploring the use of standards and operating procedures to minimize increases in staff levels was also discussed.

- Many agencies are looking at the prospect of not being able to hire to fill vacancies due to agency downsizing and budget constraints. This forces contracting out for operations and maintenance activities.

Institutional Issues

- The mindset of more experienced personnel and the traditional way of doing things may be institutional issues that will need to be addressed in the deployment of ITMS.

- It was noted that institutional problems may emerge in maintenance as well as in operations.

- A team effort is needed to address institutional issues before building complexities into the systems.

- The culture of many state departments of transportation can be a problem with the deployment of ITMS. Most state departments of transportation still have a traditional highway orientation and a construction focus.

- Some cities and groups may be suspicious that ITMS is just a technology toy. New technologies have not been embraced by significant parts of these organizations in many cases.

- Educational and outreach activities are needed to communicate the benefits of ITMS.

- The issues of turf, trust, and threat were discussed.

- The organizational structure of traditional transportation agencies, which is fairly inflexible, can work against the most efficient operation.

- Another problem in some transportation agencies is that maintenance and operations personnel are not looked upon as equals. There is a need to promote a team approach within an agency as all functions are important.

Funding Issues

- It is often hard for transportation agencies to draw positive attention and funding to ITMS when competing for limited resources with police, fire, emergency services, and other groups.

- Funding constraints are often a major roadblock to the ongoing maintenance of ITMS.

- There is a need to establish a line-item budget amount for operations and maintenance based on life cycle costs in the early planning stage.

- The potential for establishing dedicated funding for traffic operations was discussed. Although there are some benefits from having a separate source of funding for traffic operations, there are also some drawbacks.

- It is not realistic to believe that local funding, as well as state funding, can come from primarily general revenues.

- In some areas, local jurisdictions are competing against the region for funding. If one community gets funding one year, they have less chance in the next few years. The suggestion was made to establish federal matching to maintain ITMS operations and that life-cycle support is needed.

- Funding of training is also needed. Needed training programs may not be available locally, and federal funds and programs should be examined.

Based on the initial discussion of these issues, the workshop participants identified the five major concerns related to ITMS operations and maintenance. Action items to address each of these issues were also identified. The following summarize the five items identified for priority consideration.

Issue-Performance guidelines are needed for ITMS operations and maintenance elements.

These guidelines should identify expectations for the delivery of services to public and private users. The guidelines should also reflect a range of site-specific conditions rather than absolute national standards.

Actions

- FHWA and AASHTO should consider expanding upon and updating the NCHRP ***Malfunction Management*** Report. This should include information on surveillance, control, driver expectations, and other common ITS elements.

- FHWA should consider coordinating the preparation of a report on staffing guidelines for ITMS maintenance and operations. The recent ITE report on operations and maintenance practices could be used to help in this effort.

- FHWA should consider establishing a national laboratory for testing and evaluating ITMS equipment and systems, and providing for the national distribution of results.

- FHWA should consider establishing an electronic bulletin board for the sharing the experiences with various ITMS technologies.

Issue-Consideration should be given to developing funding for operations and maintenance programs on a life-cycle basis.

The identification of realistic life-cycle lengths and costs should be included in this effort.

Actions

- FHWA should consider initiating a research study to compile and maintain ITMS life-cycle data.

- Federal, state, and local agencies should be encouraged to provide life-cycle support with dedicated funding, including replacement as needed, of ITMS elements,

Issue-Establish inter-jurisdictional ITMS teams,

Establish early involvement of all inter-jurisdictional ITMS team participants.

Actions

- The lead agencies in ITMS should be encouraged to establish agreements between all participants at the beginning of the planning process to support long-term system operations and maintenance.

- ITMS teams should be encouraged to establish and agree on detailed operations and maintenance plans prior to design completion.

Issue-Incorporate operations and maintenance considerations into the ITMS design process.

Maximize the inclusion of operations and maintenance issues within the ITMS design process.

Actions

- Inclusion of operations and maintenance staff within the ITMS design team should be encouraged.

- The development of national and regional clearinghouses for gathering and distributing best practices for servicing and maintaining principle system components should be encouraged.

- The utilization of existing hardware and software standards should be encouraged whenever possible.

Issue-Address future ITMS staffing needs.

This should include the recognition that long-term public agency downsizing will require greater utilization of contract personnel for operations and maintenance. It should also consider inter-agency resource pooling opportunities for optimal staffing of ITMS operations and maintenance requirements.

Actions

- Model private agreements for contracting and inter-agency agreements for pooling staff resources should be developed.

- The inclusion of technical disciplines, compensation, and career path requirements for operations and maintenance personnel should be encouraged.

Summary of Common Themes and Ranking of the Top Issues

Dennis L. Foderberg, University of Minnesota

I was asked to observe the different workshop sessions and to help identify a few common themes from the various groups. You have been asked to select the five top issues that need to be addressed to help advance ITMS. I will review the results of the voting at the end of my presentation. As described by the previous speakers, each of the workshops identified the top issues and research needs in their area.

I had the opportunity to sit in on each of de workshops and to listen to the discussions in the different groups. All of you are to be complimented on your participation. Each of the workshops had spirited discussions on the key issues and potential action steps within their focus area.

I think the opening session did an outstanding job of setting the tone for the Symposium. One of the key points made by all the speakers was the need to focus on the whole transportation system, not just traffic management. The need to involve all groups early and throughout the planning, design, implementation, and operation of ITMS was also made. These, and other themes, were supported by the other speakers and by the discussions in the workshops.

Eight major themes seemed to emerge from the workshop discussions, as well as the general sessions. I would like to highlight each of these eight themes and present some additional ideas for your consideration.

First, all of the workshops discussed the need for communication and coordination among all of the groups involved in planning, designing, funding, implementing, and operating ITMS. The importance of open and continuous communication was stressed as a critical element of successful projects.

Second, the need for the early involvement of all groups was stressed by speakers in the general sessions and by participants in the workshops. It was noted that the diverse agencies and groups involved in ITMS make this early involvement more difficult, but also more important. The participation of not only multiple agencies, but also different groups within these organizations, as well as the private sector, will be critical to the success of ITMS.

Issues related to different aspects of operations and maintenance were discussed in all of the workshops. Although this was the major focus of one of the workshops, the need to consider operations and maintenance issues related to legal concerns, system integration, and agency roles and responsibilities were discussed in the other workshops as well.

Questions about liability concerns were also raised in all of the workshops and a wide range of potential issues were discussed. This appears to be an area where additional research is needed to help ensure that possible liability problems are identified and addressed early in the ITMS planning process.

Funding also emerged as a major concern in all of the workshops. Ensuring adequate funding for all aspects of ITMS-from planning and design to system procurement to operations and maintenance-was identified as a top priority. The roles of various governmental levels in funding ITMS were discussed, and there seemed to be agreement in all of the workshops that innovative approaches which maximize available resources from all groups will be needed to advance the deployment of ITMS.

Institutional issues were raised throughout the discussions in all of the workshops. The roles and responsibilities of various groups were debated and good case study examples were presented. The need for a project champion emerged from many of the groups as a key element to successful projects.

Federal and state legislative needs were discussed in most of the workshops. The responsibilities of these two levels were identified, and legislative initiatives related to ITMS and ITS were outlined.

Finally, the need for partnerships-public/public, public/private, and private/private-was brought up in all of the workshops. There seemed to be agreement that there is still much to be learned about developing and maintaining these partnerships. The major element of these discussions focused on ensuring that the key people and groups are involved in the partnership.

The workshop results provide an excellent summary of the key issues and opportunities associated with advancing the deployment of ITMS. The action items present a good starting point for the development of a strategic agenda for ITMS.

The results of the ranking of the top five issues and actions indicate a good deal of consensus among the Symposium participants. The top concern-the need for revisions to contracting procedures-was rated well above the others. There were five issues rated fairly closely together after this element. As a result, the following top six issues and actions relating to ITMS were identified.

Issue-The current methods of contract selection and contract award are often inappropriate for procuring advanced technologies and related services.

Action

- Efforts are needed to explore alternative contracting methods to identify changes in legislation that may be needed to allow public agencies to use these procedures, and to document the experience with alternative approaches. Additional research, including the preparation of a Synthesis, best practice examples, case studies, and model guidelines and contraction procedures would be appropriate.

Issue-Performance guidelines for ITMS operations and maintenance are needed.

Action

- The development of performance guidelines for ITMS operations and maintenance should be pursued. These guidelines should consider a range of site-specific conditions, as well as identifying the expectations and roles of different agencies and groups.

Issue-There is a need to incorporate operations and maintenance considerations into the ITMS design process.

Action

- The development of best practice examples highlighting the inclusion of operations and maintenance consideration into the ITMS design process should be encouraged, as should support for the ongoing sharing of information. Possible approaches for consideration include the development of a Synthesis, best practice case studies, papers and presentations at future conferences, and the development of general guidelines for incorporating operations and maintenance consideration into the ITMS design process.

Issue-Explore funding support for ITMS.

Action

- Efforts should be supported to examine and identify innovative funding sources and approaches, to develop best practice case studies and reports documenting different ITMS funding techniques, and to continue to highlight examples at future conferences.

Issue-Identify the benefits of system integration.

Action

- Efforts should be supported to document the benefits of system integration, to identify alternative approaches, to monitor best practice case studies, and to develop general guidelines for system integration.

Issue-There is a need to better communicate the benefits of ITMS at the local level.

Action

- The development of information on the benefits of ITMS for use with local elected officials, the public, and other groups should be supported. Encouraging the ongoing communication among all groups at the local level should be part of this effort.

CLOSING SESSION

Leslie N. Jacobson, Washington State Department of Transportation-Presiding

Use of ITMS Actions to Manage Traffic After the Los Angeles Area Northridge Earthquake

Anson Nordby, City of Los Angeles, California

It is a pleasure to be here this morning. I would like to highlight some of the benefits of a well designed and operated ITMS in my presentation. I will use the experience in the Los Angeles area after the Northridge earthquake to help identify how ITMS and the Smart Corridor project were used to help manage traffic after the earthquake. I will also mention a few of the other techniques used to respond to the damage caused by the earthquake.

The 1984 Olympics in Los Angeles provided the opportunity to develop and deploy many elements of an advanced transportation management system. These included the ATASC traffic signal control system and many other components. Managing the transportation system for the Olympics also required that numerous agencies and groups work together and coordinate their activities . This proved to be a very positive experience and set the stage for the ongoing cooperation and communication among agencies that exists today.

Los Angeles has some of the most heavily traveled freeways in the United States. For example, over 340,000 vehicles a day use the Santa Monica Freeway. Forecasts indicate that vehicle volumes will continue to grow and that freeway travel speeds will continue to decline. Increases in population are also projected.

Although the freeway system is heavily utilized in Los Angeles, there is often available capacity on parallel arterial streets in many corridors. The Smart Corridor project was developed to response to this situation. The focus of the Smart Corridor project is to attempt to balance the use of all available facilities in a heavily traveled corridor. The Santa Monica Freeway and the five parallel streets adjacent to it were selected as the first project to test this concept. The five parallel streets have about the same capacity as the freeway. By shifting some of the demand from the freeway to the arterial streets we may be able to improve the overall operations of the corridor.

A number of traffic control centers have been developed by different agencies in the Los Angeles area, including those operated by the City of Los Angeles (LADOT), The California Department of Transportation (Caltrans), and the California Highway Patrol (CHP). One of the biggest challenges was to interconnect and coordinate these traffic centers into a coordinated approach to traffic management.

One of the first steps in the Smart Corridor project was to extend the ATASC system to include the city streets surrounding the Santa Monica Freeway. Other enhancements to the system were made as well. The ATASC system provides excellent graphics showing the status of the intersection controllers, the traffic on the approaches, and it allows for ongoing diagnostics of the communications system.

A number of other elements were added in the corridor. These included changeable message signs on the arterial streets, a low power HAR, and closed circuit television cameras. The closed circuit television component provided over 70 percent coverage of the main arterials in the corridor. Caltrans, CHP, and LADOT control centers were also linked together. Much of the information generated by the system is also provided to the public. For example, the Caltrans map showing the status of the freeway system is shown on the government access cable television channel. The same information can also be accessed from a personal computer over dial-up telephone lines. Further, this information is shared among the different control centers and agencies. This helps coordinate traffic management efforts and incident response activities.

On January 17th at 4:31 A.M., a major earthquake hit the Los Angeles area. The earthquake lasted for 30 seconds and measured 6.8 on the Richter Scale. The Northridge area of the San Fernando Valley was especially hard hit by the earthquake. The earthquake knocked out all of the electricity in the Los Angeles area resulting in a loss of power in over 450 square miles of the City of Los Angeles and a considerably larger area within the county.

As you are all aware, the damage from the earthquake was very extensive. Over 10,000 buildings were damaged and the freeway and roadway system suffered major damage. A coordinated approach was needed to respond to the situation and the different agencies in the area worked closely together to return the transportation system to normal as quickly as possible.

Damage to the freeway system occurred primarily in two main areas. One was the interchange of the I-5 and the I-14 Freeways and the other was the Smart Corridor and the I-10 Freeway. Some of the connector roads along I-5 collapsed in areas with over 216,000 average daily traffic volumes. In addition, parts of the freeway were severed, isolating vehicles that were able to stop in time. In this particular area we were lucky to have an old road that was there before the freeway system was constructed. We were able to use this facility as a major detour in the area.

One thing we found out as a result of the earthquake is that if you want to find a way to get people to shift their mode of transportation, destroy your facilities. Ridership on MetroLink, the commuter rail service in the corridor, experienced a dramatic increase in ridership after the earthquake. Before the earthquake, aproximately 950 passengers a day were using MetroLink. After the earthquake almost 22,000 passengers a day were using the service. Additional cars were added to the service, five new stations were built, and other improvements were made to meet this increased demand.

Coordinating traffic in areas with older traffic signal control systems was a challenge. In some cases, we had to have engineers and technicians manually controlling the signals in the field and communicating with others through the use of radios. Gathering and disseminating information was extremely difficult in this situation. This approach obviously required extra staff resources and was difficult to sustain for a long period of time. It did help maintain traffic flow over the short term, however.

Managing traffic was easier in the Santa Monica Freeway Corridor, as the ATASC system and the traffic management system were in place. The damage to the freeway caused the equivalent of approximatley 20 lanes of traffic to be diverted onto the arterial street system managed by the Los Angeles Department of Transportation. The traffic management system in the Smart Corridor was used to assist in responding to problems in this area.

The Caltrans Traffic Operations Center began to disseminate motorist information immediately after the earthquake. Caltrans also began to identify possible detours and traffic management strategies. Work was also initiated on contracting for demolition and rebuilding of the freeways.

One of the things we did was to provide high-occupancy vehicles (HOVs) with a short detour while requiring single-occupancy vehicles to take a more circuitous detour. This helped encourage greater use of HOVs. Caltrans promoted the use of the facility and used changeable message signs to let the motorist know that there was a stiff fine for violating the occupancy requirement. The California Highway Patrol also provided visible enforcement of the lane. Further, Caltrans was able to utilize a damaged flyover ramp as a detour in another area. Although the ramp had been damaged, the decision was made to shore it up and use it as a detour. This worked very effectively.

With the detours in place, a number of basic ITS elements were used to help operate and manage the system. These included changeable message signs, HAP, and providing updated information to the public and to local officials.

Demolition of the damaged structures began very quickly. Significant incentives were provided to contractors to complete demolition and reconstruction projects early. This approach proved to be very effective and most projects were completed early. In some cases, this approach caused problems for the traffic management plans, however. Conflicts did arise in some cases when contractors in their zeal to complete projects early caused disruptions in traffic flow. Some problems occurred because contractors were not willing to follow roadway closure plans. It was difficult to manage traffic in this setting. As a result, video surveillance of construction areas was initiated to monitor activities.

This experience indicates the need for a dynamic intelligent transportation system that allows an agency to add and modify elements in response to changing conditions. For example, a new traffic signal was installed at a major intersection in six hours. A helicopter was also used to help identify potential detours and other traffic management strategies. As one of the people who assisted in this effort, it gave me the opportunity to see the whole city and to see how well the traffic management system worked.

A 60 to 180 percent increase in vehicle volumes was experienced on parallel arterial streets during the reconstruction of the freeways. Changing the timing of the traffic signal systems helped manage this additional demand, but other measures were also used. For example, on-street parking was removed in many areas, allowing an additional lane for traffic. The timing of traffic signs was constantly being adjusted and readjusted and other elements were modified in an attempt to maximize the efficiency of the system. Many of the tools and approaches we used are exactly the same as those deployed with ITMS.

As you know, the freeway system in Los Angeles was rebuilt and reopened earlier than predicted. Traffic was managed effectively during reconstruction of the freeways by dynamically changing plans and detours on a daily basis. From driving through the corridor on a regular basis and from observing the area from the air, I would say that the capabilities of the traffic management systems in the area are tremendous.

Although I would not recommend an earthquake as a way to test ITMS, our experience showed that the system worked very effectively. I think we are moving into a new era of transportation management in this country and the next few years should be an exciting time in the profession.

A Look Ahead to the 3rd ITMS Symposium in Boston, June, 1996-ITMS Activities in the Boston Area

Michael Costa, Massachusetts Highway Department

It is a pleasure to have the opportunity to provide an overview of transportation activities in the Boston area and to extend an invitation to join us in June of 1996 for the Third ITMS Symposium.

Because this session looks ahead to next year, I would like to take a few minutes to talk about the Boston area. By attending the Symposium you will have the opportunity to see the Swan boats in the downtown Public Garden, Faneuil Hall Marketplace, the USS Constitution, the Bunker Hill Monument. If you come to Boston, you will also be able to see another sight-traffic congestion.

ITS is one of the tools Massachusetts is using in the development of an integrated transportation management system to help address congestion in the Boston area. A comprehensive ITS program has been established over the last two years.

The first step we undertook in this effort was the development of a strategic deployment plan for the metropolitan Boston area. The consulting firm of JHK & Associates was selected to conduct this planning effort, which was completed in January of 1994. The purpose of this plan, which was funded by FHWA, was to examine the existing conditions in the Boston area, to identify targeted ITS user services, and to develop a phased implementation plan for ITMS and other ITS projects.

One of the challenges in the Boston area is coordinating the activities of the numerous agencies responsible for different aspects of the transportation system. These include the Massachusetts Highway Department, the Massachusetts Turnpike Authority, the Massachusetts Port Authority, the Massachusetts Bay Transit Authority, and several cities and towns. Developing an ITMS with all these agencies represents a major challenge. Our planned approach is to utilize a Traffic Information and Coordination Center (TICC) as the focal point for the system.

The strategic deployment plan recommended a two phased approach. The first phase focuses on downtown Boston and out to Route 128, which is a circumferential highway around the city. The Central Artery project, which you will hear more about in the next presentation, is included in the first phase. The second phase will include the TICC and will expand the system to the I-495 Freeway and other metropolitan areas around the state.

I would like to briefly describe four ITS projects that are underway as part of the first phase of deployment. There are the Route 128 project, the SmarTraveler Operational Test, the Southwest Expressway HOV lane, and an Integrated Transportation Management System on the I-93 Freeway north of Boston.

The Route 128 corridor project focuses on the development of an enhanced emergency management system. The project is building on existing incident management efforts including the *SP Program and the Motorist Assistance Program. The state police receive approximately 25,000 cellular telephone calls per month on incidents and accidents through the *SP Program. The Motorist Assistance Program is a public/private project that provides free roadside assistance to motorists on 20 routes in and around Boston utilizing roving service vans. Approximately 7,000 motorists are assisted each month through this program. We want to build on these efforts to develop an automated incident detection system along the Route 128 corridor. Field equipment including loop and radar detectors, closed circuit television cameras, and changeable message signs will be installed along approximately 225 lane miles of highway. A key component of this system will be the construction of a regional traffic operations center (TOC) co-located in the State Police barracks in Framingham. Leased lines will be used initially for communications. However, an initiative called "Wiring Massachusetts" is also underway to foster public/private partnerships for the development of a fiber optic backbone throughout the metropolitan Boston area. The design of this approximately $7 million project should be complete within the next six months.

The SmarTraveler project has the distinction of being the first operational test funded under the ISTEA. It is a region-wide, real-time traffic and transit telephone information system provided as a free service in the Boston metropolitan area. The SmarTraveler project uses the fusion of multiple information from a data collection source in a Unix driven, multi-mode, multi-port, audiotext system developed by SmartRoute systems. Currently, the SmarTraveler project has approximately 500 mobile telephone probes in and around Boston, 50 live and slow scan cameras, and direct links to the state police and various transportation agencies.

Overall, the service monitors approximately 700 miles of major roadways, as well as bus, rapid transit, and commuter rail lines. The service receives about 1.5 million calls annually. One of the most interesting statistics is that 97 percent of the people contacted in a small sample survey conducted after the first year of the test indicated that they liked the service well enough to use it again. That survey also obtained information on the impacts of the service. Approximately half of the callers indicated they made some change in their travel behavior based on the information received from the SmarTraveler System.

The third project is the Southeast Expressway HOV lane which is currently under construction and scheduled to be completed in late 1995. The I-93 Southeast Expressway is located south of Boston and carries approximately 190,000 vehicles per day. Twelve miles of a moveable barrier system, 6 miles in each direction, is being installed to create an HOV contra-flow lane using the off-peak travel lane. A barrier transfer vehicle will be located on each end of the project and wilI move the barrier in and out from the median each weekday morning and afternoon. Once the lane is separated, high occupancy vehicles will be allowed to bypass congestion to and from Boston. Because of the limited lane width and single entrance and exit points, efficient emergency management will be a key component of the operation of the facility. ITS technology will be used to monitor operations and enhance incident detection and response. The collection and processing of field data will be performed at a satellite control center located at the facility.

The last project that I would like to mention is the I-93 ITMS Operational Test. This project focuses on providing multimodal, real-time, en-route motorist information to travelers coming into the City in the morning peak-period. The goal is to monitor corridor conditions, and utilize simulation models to estimate traffic conditions 10 to 15 minutes into the future. The project will provide commuters with information and recommend actions prior to their reaching decision points to allow them to divert to an optimal mode or route.

The study area for this project is the I-93 Freeway corridor north of Boston. I-93 is a heavily congested roadway, which includes a permanent HOV lane. Alternate routes are available by using Route 28 and Rutherford Avenue. Both roadways are signalized arterials that currently have closed loop signal systems. The area also includes transit alternatives and several commuter parking lots. Although it is a small study area, it includes all the elements that need to be included as part of an integrated system. The operational test, which is currently being designed by AlliedSignal, will challenge the application and integration of ITS technology. Key elements with nationaJ significance include monitoring individual behavioral responses to multi-modal, real-time information, the inclusion of adaptive signal controls, and the application of dynamic and predictive traffic simulation models. The operational phase of the project is scheduled for the summer of 1996.

This is a small sample of the many projects underway in Massachusetts. I hope you will be able to join us in Boston next year for the Third ITMS Symposium and have the opportunity to see these and other projects firsthand.

ITMS and the Central Artery Project

Sergiu Luchian, Massachusetts Highway Department

Thank you and good morning. I am happy to have the opportunity to talk about the Central Artery Project in Boston. The Central Artery is the portion of the I-93 highway that cuts through the middle of the city. It separates the waterfront area of Boston from the financial district. The freeway, which was built in the 1950s, presents a physical barrier in the downtown area. The freeway was designed for 75,000 vehicles a day, but it currently carries about 200,000 vehicles a day. As a consequence, it often seems that we are the operators of the largest parking lot in the northeast. The Central Artery has three traffic lanes in each direction and ramp accesses are placed fairly close together. In many respects, I-93 in this area works more like a collector distributor than an interstate highway.

Planning for the Central Artery tunnel project began in the 1960s. At that time, consideration was given to adding another crossing to Logan International Airport. That plan was expanded, however, and the current project focuses on adding a Third Harbor Tunnel which will have two traffic lanes in each direction. The new facility will double the capacity of the existing Sumner and Callahan tunnels. It will also improve the I-93 (Central Artery) by increasing capacity by a third and depressing it underground.

The total cost of the project is estimated at $8 billion. Currently, approximately 90,000 vehicles a day use the existing tunnels. By 2010, some 300,000 motorists are projected to use the three tunnels on a daily basis. The design for the Central Artery Tunnel is very complex. Some of the interchanges will be underground, which will add complexity for motorists as well.

Maintaining air quality levels in the tunnels also had to be considered. All tunnels are designed for travel speeds of 50 mph. The goal is to ensure that vehicles do not spend more than approximately 15 minutes traveling through the tunnel. Two elements are key to the approach taken to address air quality concerns. One is the ventilation system and the other is the incident management program.

The ventilation system for the tunnel includes over 130 fans and eight ventilation buildings. A very aggressive incident management program is in operation with the existing tunnels. This program will be expanded to include the Third Harbor Tunnel. We have been working with the fire department since 1987, and they have been involved in the design and procedures to be used for the facility. An abandoned tunnel in West Virginia was used to test different operating strategies and responses to fires and other emergencies.

The entire underground highway system will be managed by au operations control center. This center will operate 24 hours a day. Closed circuit televisions will be used to monitor the tunnels, as well as the freeways. There are currently nine emergency stations and platforms located throughout the project. These are located to provide immediate access to any point in the tunnels. The operations control center will coordinate all of the. elements associated with the system. The entire system is triply redundant to ensure that backup power and other functions will be available in the case of an emergency. There are 28 backup generators and a smaller backup operations center. The backup center includes primarily the life safety systems, including the communications network.

Other elements of the traffic management system include lane use signals, changeable message signs, 500 closed circuit television cameras, carbon monoxide detectors, hydrocarbon detectors, HAR, fire detectors, and a fire alarm system.

The traffic management system will also be used during the construction of the Central Artery and the Third Harbor Tunnel. A pilot program is currently underway which includes four variable message signs.

The Massachusetts Institute of Technology (MIT) developed a traffic simulator that has been used to run different traffic management scenarios. This simulator has been extremely helpful in testing different approaches to traffic management.

The first phase of the Central Artery Tunnel project is scheduled to be opened in December of 1995 for commercial vehicles only. You will be able to see the project next year at the ITMS Symposium in Boston.

A number of additional ITS technologies are being incorporated into the project. The toll facilities associated with the tunnel wilI be fully automated. The technology for the electronic tolls has not been selected yet, but a number of different systems are being considered. The use of in-vehicle navigation technologies, real-time asset management systems, and other ITS components are being explored to help ensure the safe and efficient operation of the Central Artery and the Third Harbor Tunnel.

I hope you will make time to see these facilities next year at the ITMS Symposium in Boston. Thank you.

INTEGRATED TRANSPORTATION MANAGEMENT SYSTEMS DEFINITION OF THE CONCEPT

Thomas Urbanik II, The Texas Transportation Institute

INTRODUCTION

The scope of this paper is a definition of the concept of Integrated Transportation Management Systems (ITMS). ITMS is an evolving concept and depends partly on ones experience and philosophy concerning integration of the various component systems of the current surface transportation system. ITMS is a concept whereby the users of the transportation system benefit by integration of various component sub-systems which have largely evolved due to the institutional structure of the transportation system. The transportation system is in fact fragmented due to multiple agencies, multiple jurisdictions, multiple modes, and multiple disciplines being responsible for various aspects. This specialization, while improving the efficiency of various components, is a detriment to a global view of system management.

As concerns have developed due to a variety of issues including congestion, the environment and limited resources, a more global perspective is being offered as a means to improve the effectiveness and efficiency of the surface transportation system. ITMS is a step towards a more global view of the transportation system. Existing institutional arrangements would suggest that the process will be evolutionary in nature and varying across the country. The key to success will be an understanding of the mutual benefits of a more integrated system. Not that competition can or should be eliminated, but that benefits due accrue from appropriate collaboration. The paper provides a current definition of ITMS and begins to identify innovative ideas and practices for improving transportation management in metropolitan areas by focusing on the challenges and opportunities. ITMS is as much a process as it is a specific concept.

THE LAW

The enactment of the Clean Air Act Amendments of 1990 (CAAA) challenged the transportation profession to maintain the Nation's mobility while enhancing our air quality (1). The CAAA established criteria for attaining aud maintaining National Ambient Air Quality Standards (NAAQS). These requirements specify the actions required to be taken by nonattainment areas. An area is designated a nonattainment area by the Environmental Protection Agency (EPA) when it does not meet the NAAQS. Although the CAAA only directly effect the 198 designated areas. Other urban areas are potentially impacted if they cannot maintain their air quality.

The CAAA mandate a State Implementation Plan (SIP) that contains procedures to monitor, control, maintain, and enforce compliance with the NAAQS. The SIPS include Transportation Control Measures (TCMs) to reduce emissions of air pollutants from transportation sources by improving traffic flow, reducing congestion, or reducing vehicle use (2).

Closely following the CAAA was the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). ISTEA established a new vision for surface transportation in America. Its goals included reduced congestion, maintenance of mobility, an enhanced role by State and local governments, and additional focus on environmental issues. The programs include a National Highway System, an Interstate Program, a Surface Transportation Program, a Congestion Mitigation and Air Quality Improvement Program, a Bridge Replacement Program, a Federal Lands Program, and Special Programs. These programs provide the primary federal funding mechanism for surface transportation. They also set a new direction for surface transportation that is supportive of ITMS (2).

ISTEA has other important provisions that are relevant to ITMS. Transportation planning must be more broad based and include additional considerations such as land use, Intermodal connectivity, methods to enhance transit service, and needs identified through management systems. Management systems include highway, pavement, bridge, highway safety, traffic congestion, public transportation facilities and equipment, and Intermodal transportation facilities and systems. In addition, the Act requires a statewide planning process, a statewide transportation plan, and a statewide transportation program (3).

The importance of the law it that is provides a framework for a broad approach and a philosophy that is consistent with ITMS.

THE CONCEPT

ITMS is the creative use of existing systems and requirements to provide a systematic approach to the surface transportation system. ITMS is a process to enhance mobility by making more effective use of existing facilities through ***systematic*** monitoring, evaluation, prioritization, and implementation of operational management strategies. Within this context, ITMS includes traditional Transportation Systems Management (TSM) concepts. However, it does NOT consider TSM as a short term or stop gap approach. It considers TSM as one of many tools to manage the system. Tools would include Congestion Management Systems (CMS), Travel Demand Management (TDM), Transportation Control Measures (TCMs), Intelligent Transportation Systems (ITS), and others.

ITMS is, therefore, the process that ties the various programs into an integrated package to increase mobility. It is a philosophy that the delivery of transportation services should be transparent to the user and be done in an efficient manner that is also responsive to local needs. ITMS includes those institutional relationships necessary to support the mission of the transparent delivery of transportation service across modes and inclusive of police, fire, towing, and emergency medical services necessary for effective system performance.

Perhaps a few examples of what ITMS is would be illustrative of the concept. ITMS is multi-modal, but not in the sense of just considering transit as a separate mode. It is the integration of transit, as a full partner, into the operation of the transportation system, not as a separate consideration. It includes the integrated response of police, fire, ambulance, and wrecker services to major incidents. It is the integration of high occupancy vehicles into the overall system as a basic planning consideration. It is the full consideration of pedestrians and bicycles in system operation with full appreciation of the importance of these self powered modes as a part of the system, not as a nuisance to be considered after all other issues.

ITMS is multi-jurisdictional and multi-disciplinary because users do NOT expect city limits or city departments to be reasons for systems operating inefficiently. For example, travelers expect that emergency response services will be provided in a prompt manner, not expecting to deal with the need to identify the multitude of agencies necessary to deal with a major incident.

The scope of ITMS will vary by location. Large urban areas will have very sophisticated systems providing a wide range of user services. Small urban areas will have more limited needs due to a less congestion environment. The important point is the opportunity to improve the efficiency of transportation services by irmovative ideas and practices through the proper application of technology and operational procedures.

THE GOAL

"The basic goal of ITMS is ***effective and efficient transportation. Effective transportation*** is defined by consumer needs. It is safe, convenient, economical and reliable. An ***efficient system*** is one that can meet the collective needs of consumers at a cost acceptable to users, taxpayers and the environment" (3).

RELATED ACTIVITIES

There are a variety of related activities that complement, take advantage of, or provide input into ITMS. These activities exist as the result of a number of existing programs largely resulting from Federal law as previously delineated. Congestion Management Systems (CMS) were mandated by ISTEA as a statewide process for metropolitan areas with a population of 200,000 or more. "CMS is a systematic process to provide information on transportation system performance and alternative strategies to alleviate congestion and enhance the mobility of persons and goods. A CMS includes methods to monitor and evaluate performance, identify alternative actions, and evaluate the effectiveness of implemented actions" (4) The CMS is a performance-based system which is intended to effectively manage existing and new transportation facilities through the use of Travel Demand Management (TDM), Transportation Systems

Management (TSM), and capital improvement projects. The CMS is a system to monitor and analyze the magnitude of congestion on a multi-modal transportation system in order to plan and implement appropriate actions to enhance transportation system performance. A CMS can take advantage of an ITMS and also provide input in ITMS operation.

TDM is a class of management strategies carried out to reduce effective travel demand by modifying trip-making behavior. The purpose is to achieve efficient use of transportation facilities by reducing drive-alone auto trips (single-occupant vehicles, SOVs), and to minimize costs of roadway expansion for SOVs. Some TDM strategies may be implemented in an ITMS.

TSM is a class of management strategies carried out to improve management of the supply and use of existing transportation facilities. TSM strategies are designed to increase effective capacity of the existing system without major capital investment in new facilities. TSM Strategies tend to be low cost, to require minimum right-of-way, and to be rapidly implementable compared to new construction. Some TSM strategies are more effective when implemented in an ITMS.

NATIONAL ARCHITECTURE AND STANDARDS

The implementation of ITMS implies the need for an ITMS System Architecture. A system architecture provides a framework that describes how the various sub-systems (e.g., traffic signal sub-system, freeway traffic management system, traveller information sub-system, etc.) Interact and work together to achieve total systems goals.

Development of a system architecture should be done using a system engineering process. System engineering is the process that turns operational needs in system performance parameters, assures compatibility of all the technical components, and deliveries a satisfactory product on time and on budget. This structured approach assures that the end product is truly a system, not a loosely coupled group of systems.

INSTITUTIONAL CONSIDERATIONS

The institutional component of ITMS is perhaps the most important element in making ITMS happen. It will be an important component of the Symposium. In most metropolitan areas, the transportation system is managed and operated by many different agencies and multiple jurisdiction. These agencies represent various modes and functions. Therefore, to better manage and operate the system requires coordination and implementation by many agencies and jurisdictions. This coordination and implementation is difficult because of the multiple and sometimes conflicting objectives of the different agencies and jurisdictions. These differences of perspectives and willingness to participate must be addressed when discussing how the transportation system should be operated and managed.

Mechanisms for bringing about the institutional framework for ITMS are in their formative stages. There have been only a few success stories on beginning a broader framework for implementing ITMS. The Symposium with present some of the best efforts currently underway around the country. TRANSCOM in the metropolitan New York area was one of the first multi-jurisdictional and multi-modal undertakings to improve operations is a multi-state region. Houston, Texas has also had some success with multi-agency and multi-modal cooperation on both construction and operation of integrated multi-modal facilities primarily for HOV. Houston is now embarking on a multi-agency transportation management center. These efforts, while representing major accomplishments in ITMS and perhaps the most comprehensive approaches to ITMS, still do not yet represent an ideal ITMS.

The San Francisco Bay Area has identified seven major reasons that ITMS is an extraordinarily difficult task which helps explain the limited success to date (2):

1. The streets, highways, mass transit systems, railroads, trucking companies, ports, airports, and terminal facilities which make up the transportation system are operated under separate management. Managerial independence is a jealously guarded prerogative.
2. The modal components of the transportation system are managed according to service and efficiency standards particular to each mode. There is little agreement on measures of overall system efficiency that reflect consumer

needs or overall social and environmental costs.

3. The service requirements of an efficient system are different for the peak and off-peak periods. During commute hours, job access is the most critical test of system efficiency. During non-commute hours, the most critical test of the system's efficiency is its ability to move freight and deliver goods reliably and economically. An efficient system must reconcile both needs-and meet both tests.
4. Private enterprises can be managed efficiently because companies can pick and choose what markets to serve. Not so the transportation system. The transportation system must provide universal service. And it must serve all comers-even if its capacity is already oversubscribed. Faced with excess demand, most transportation providers cannot turn away customers or price their services higher.
5. The demands made on the transportation system are a by-product of local land-use decisions and location choices made by households and firms. Transportation providers have virtually no influence over these choices. Nor does increasing congestions provide an effective or efficient way to steer growth and development.
6. The requirements of an efficient system vary from place to place because of geographic diversity and unique topography. The diversity makes it difficult to agree on a strategy of system management because no one strategy fits a region's many needs.
7. Some methods of system management create "winners" and "losers" among agencies and jurisdictions. These measures have met predictable resistance and are unlikely to gain acceptance until they have been reconfigured as win/win alternatives.

The goal of ITMS is to improve the efficiency and effectiveness of the surface transportation system. The thrust of ITMS is that modal, jurisdictional, disciplinary, and institutional elements of the transportation system should be operated, managed, planned and improved from the perspective of one integrated transportation system even though it is composed of many "systems" due to the various institutions responsible for the system. Key elements of ITMS include communication and partnerships among agencies and jurisdictions. In addition, a process must exist to put all the necessary pieces together.

Experience in New York, Houston, and the San Francisco Bay Area suggests the process is still evolving. It is not possible to start off developing a comprehensive plan on a regional level. Limitations include the inability to use explicit performance measures and detailed evaluations of alternatives. Initial successes have focused on operational improvements in a corridor. The idea of regional optimization of does not appear feasible at this time. To successfully manage the transportation system, the connection between planning and implementation must be made from both ends. It was concluded that communications and partnerships are as or more important to the management of the transportation system than technical sophistication and refmement of the tools (5).

PLANNING AND DECISION CONTEXT

Although it is assumed that managing to improve efficiency and effectiveness will improve mobility for people and freight, it is not clear how to evaluate projects from the broadest perspective. How does the process resolve conflicting community objectives? Are only those projects which are non-controversial implemented? How does the process resolve trade-offs such as freeway widening versus congestion pricing? The dilemma is there is no clear cookbook answer to complex issues.

The San Francisco Bay area has proposed a process to deal with the tradeoffs (3). The process must include agreed upon ground rules or precepts that will allow partners to better define strategies in a way that potential conflicts can be resolved. The objective is to obtain projects that are more acceptable or neutral to partners.

It is also necessary to realize that capital and management projects cannot be considered in isolation. Planning which only considers management projects first and capital strategies second will result in poor management strategies and poor capital projects.

The previous analysis leads to a strategy for improving the efficiency and effectiveness of the transportation system (3). The strategy:

Focuses on ITMS;
Provides a system context for interagency decisions;
Provides a multi-modal context for management decisions;
Provides a region-wide commitment to develop and implement management systems, integrated to the extent feasible as the elements of a management strategy; and
Is seen as a continuing, vital endeavor essential to support the region's transportation investment.

THE SYMPOSIUM

The ITMS Symposium is intended to help define the concept of ITMS as well as help understand the concept. As much as the definition of the concept is difficult, it pales by comparison to the difficulty in implementation. In actual practice, ITMS will become a reality through incremental improvements in the existing process by building institutional bridges between diverse agencies, modes and disciplines with individual missions.

The Symposium is organized in a way to provide different views of ITMS. White papers will be presented that look at ITMS from different views. These views include multi-jurisdictional, multi-modal, multi-disciplinary, systems integration, and environmental. These views help to define the complexity of the issues involved, they do not provide a road map to a solution. Later in the symposium, a framework will be established for understanding why ITMS is important. Then several case studies will be presented which focus on the integration aspects of ITMS. The Symposium will then continue by focusing in on some of the technical details including Legal/Procurement, Operations and Maintenance, Systems Integration, and Roles and Responsibilities. The Symposium will then bring the participants together to identify key issues and prioritize future needs. The Symposium will conclude by summarizing the findings including the identification of key issues and actions recommended to address them.

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INTEGRATED TRANSPORTATION MANAGEMENT SYSTEMS

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The recent focus toward development of Transportation Management Centers (TMC) has created an opportunity for transportation professionals to interact in an expanded manner with many nontraditional disciplines. For TMC's to be fully effective, Integrated Transportation Management Systems (ITMS) must be developed which require the participation of a diverse set of technical and non-technical disciplines.

Developing an ITMS is a far reaching undertaking that can include a variety of functional components that vary by locality needs and resources. ITMS can include procedures relative to incident response, physical components associated with traffic, transit and parking systems and the actual control command center from which systems and procedures are managed.

For successful operations, the proper mix of elements must be brought together and through effective management produce a workable product. The many diverse multidisciplinary elements that compose ITMS are the things that make its products so useful and conversely so difficult to mange on an ongoing basis.

This paper identifies the various disciplines and functional groups that should be involved in developing an ITMS. It discusses the process of identifying disciplines, the relationship between them and relates them to the various development phases.

RELATIONSHIP BETWEEN DISCIPLINES

An effective ITMS can not operate unless a diverse group of disciplines participate in all phases of its development. Numerous disciplines are dependent upon other disciplines to effectively accomplish their work responsibilities. Unless activities are coordinated and performed cooperatively, system results will be significantly below acceptable levels. Disciplines must complement one another rather than being absent all together or competing with one another.

To achieve the usually desired goal of responsive incident management and effective management of transportation systems a significant amount of preparation and contributed resources is needed. These resources include developing initial and ongoing community support for program activities and their resulting financial resources, technical design support to physically construct system components, administrative and legal efforts that allow construction and daily operations to occur and ongoing maintenance of system components to ensure their availability.

In the development of many ITMS's there is a tendency to focus on those elements that the individuals responsible for developing the program are most knowledgeable about, that being traffic/freeway operations. As a result of this focus considerable efforts in both time and money can easily be consumed dealing with just a small element of the total effort that is necessary to develop an ITMS. This narrow focusing is not unique to ITMS development but occurs in many other transportation projects. The unique aspect associated with ITMS's is that for effective operations to occur, a very wide range of disciplines must be involved which traditionally have not worked together or have not worked well in previous encounters. This might include traffic and transit, traffic and police/fire, traffic and wrecker services and traffic and information provides. In general, disciplines have not totally recognized the resources available in other areas and have taken the attitude that they can perform internally at equal or better levels. As a result of this attitude and "turf building," undesirable relationships have developed in many communities to the point that disciplines compete with one another for management and operation of the same component.

If management centers are to become fully effective and integrated, a broader thinking approach must be taken such that contributing disciplines are included in all phases of operations. This becomes even more important when you must consider the situations where more than one physical TMC exists in an area representing multiple jurisdictions with multiple disciplines in each. As has been the experience with many other projects, creating early awareness of program activities and including all disciplines in this phase, usually results in a smoother implementation process. Attempting to add disciplines and functional work groups in mid steam or at the end of a project usually results in a restart of many program activities. It also creates an unfriendly environment since groups not involved in the initial decision making are now being told what to do or how things will be accomplished.

PROCESS OF IDENTIFYING DISCIPLINES

Identifying and including various disciplines and functional work groups into an ITMS is highly dependent upon the operational mission of the TMC. Identifying the responsibilities associated with a TMC is a key first step which ultimately determines the overall size and complexity of management functions. Typically, ITMS are usually responsible for incident management and signal control functions. In today's expanding transportation management structure, a number of additional roles could easily be included and in many cases are being incorporated in ITMS. These include responsibilities associated with:

Multi-modal-roadways/bus & rail transit
Travel Demand Management
Transportation Management
Parking Management
Transportation Information Systems
Commercial Vehicle Operations (CVO)

Each of these responsibilities while relating to one another, significantly expand the disciplines and functional work groups that would be involved in an ITMS. In addition to these responsibilities, local needs within a community will also influence the orientation and operational importance of a TMC. These local needs could be associated with issues such as freeway congestion and incident management, tunnel and bridge bottle necks, and snow and ice removal. As a result, the responsibilities and associated goals and objectives of a TMC can vary significantly from community to community, which in turn determines agency and discipline participation.

The mission or responsibilities assigned to an ITMS change over time depending on the community's needs and success in performing operations. Expanded roles will create the need for additional functions to be integrated in the future and more optimally, to be considered in the initial planning phases of a system. The greater the flexibility in system design, operating policies and administrative structure, the greater the opportunity to easily accommodate new or expanding disciplines.

Beyond defining initial responsibilities, a valuable process that helps to identify necessary disciplines is concept planning or operations needs analysis. This process can be undertaken by both existing and newly created ITMS's. For existing ITMS's this process can easily become the catalyst that overcomes past and sometimes negative relationships between disciplines by taking a fresh approach and look at existing situations.

During this operations needs assessment, a detailed analysis is undertaken to determine specifically:

- What program functions could/should be performed by the TMC?
- What agencies and disciplines should be involved to perform these functions?
- How system elements should be integrated from a physical hardware/software perspective?
- What standard operating procedures are needed to define agency/discipline responsibilities?
- What program phasing schedule is needed to correspond to agency programs and resources?
- What are the discipline/agency responsibilities for each phase of program development-planning, design, operations and maintenance?

Through this process existing functional participants more clearly define their specific roles as well as the identification of other disciplines that are necessary for effective operations. This in turn becomes a heuristic process wherein the newly defmed or participating disciplines provide additional insight into the specific components that are desired or necessary. This heuristic building process produces two primary products. Initially it identifies new or rejustifies the need for participation by specific disciplines. Secondly, it creates a team building process whereby functional groups become more involved in the integration process and recognize the benefits of their participation or rationale as to why or how elements must operate. As a result, the disciplines become stake holders and associate ownership into the system which in turn strengthens their participation. This identification approach and ongoing development effort is similar to those strategies associated with Total Quality Management (TQM). The wide variation in the types of disciplines and the need for substantial interaction between nontraditional technical and non technical working groups, creates a need for a high level of understanding and team building trust.

Creating this trust and team building is not easy and usually can best be accomplished through the development of successful subtasks. Using the benefits and relationships developed in an initial success creates the desire and justification for another success-"success builds success." Consequently, when developing an ITMS and bringing together a diverse set of disciplines it is important to grow the process at a rate which is compatible with the issues and social decision making process of each work group. Creating success is the easiest method of including new and expanding the roles and effectiveness of existing disciplines.

TYPES OF DISCIPLINES

The inclusion of functional work groups or disciplines into an ITMS encompasses a broad range of technical and non technical elements. These disciplines can include such elements as traffic and transit operations, public safety(police, fire), maintenance functions, computer operations, traveler information services and legal counsel. Each discipline plays a role in some phase of a TMC's design and ongoing operations. Disciplines can be viewed from several perspectives ranging from those associated with daily operations of incident response to ones involved with the physical design and maintenance of system components. For effective operations and a truly integrated management system, numerous disciplines must be brought together in each major phase of ITMS development. Determining specifically which disciplines to integrate and when is a function of the responsibilities associated with a TMC and the local community environment. Table 1 provides a list of disciplines that could or should be included in an ITMS. The disciplines are divided into three major categories consisting of Technical, Operational and Administrative/Community areas.

Technical Disciplines

Technical disciplines are those work groups that primarily contribute to the physical design of system components. Through the introduction of more sophisticated electronic, communication, video and computer technologies, a greater number of technical disciplines are now required to build management systems. The complexity of these technologies coupled with quickly changing advances, make it necessary to include experts from each discipline. Very rarely will an agency or consulting firm have a single source of expertise that spans this range of technology. Given the ever changing advances in technology and the obsolescence of equipment in shorter and shorter time frames, overall system architecture and design must be developed that is flexible to changes from a functional, time and cost perspective. Poor designs as a result of an initial lack of expertise usually hinders the functionality of the final system. This in turn creates an expectation and credibility gap for operators, elected officials and most importantly the public.

Each technical discipline will contribute at different levels of intensity depending upon the role of that particular technology or system. Even though a technology may not be significant today, it is important to include expertise from this area such that the overall system architecture is structured in an open flexible manner that can allow inclusion in the future. Additionally, a greater understanding of alternative technologies in the concept phase may alter the use of specific systems since better components or methods have been identified.

Operational Disciplines

These disciplines are those which utilize and manage the system on a daily basis, respond to incidents and emergencies and are responsible for maintenance of system components. To manage individual traffic or sub systems an array of functional expertise must be combined. Responding to incidents or managing signal systems requires the combination of many disciplines. No one agency or discipline is capable of performing the various tasks that must occur when dealing with a major traffic accident. Incident management requires considerable planning and team work and a diverse group of disciplines beyond traditional traffic/transit relationships such as police, fire, wrecker services and maintenance cleanup forces. Creating an integrated team is not an easy task since the major obstacle to over come is the social decision making structure within each discipline. Consequently, creating an empowered TMC that is aware and capable of managing these environments is critical for the establishment of a working team. The process is further complicated when dealing with private sector enterprises associated with wrecker services, equipment rental clean up crews and traveler information services. Developing contracts, procedures and assuring responsiveness with the proper equipment can be frustrating and make response efforts less effective.

Managing transportation systems such as traffic signal systems, ramp meters or parking availability systems requires the integration of associated operating disciplines. Traffic engineers, freeway operators, and parking garage managers must coordinate activities. If transit priority systems are program components, transit operations will also be involved. Integrating transit dispatch operations into an ITMS can also produce positive benefits to both traffic and transit systems by allowing transit operators(bus/train drivers) to report accidents and congestion areas. The opposite also occurs when congested areas are reported to transit operations and adjustments can be made to routes and schedules.

Maintenance operations play a vital role in an ITMS since system availability must be maintained. The increased reliance on technology for expanded program capabilities requires coordinated and responsive maintenance activities. The failure of computer or communication systems can quickly make an entire ITMS or many subsystems useless. Ongoing and emergency maintenance must be coordinated **with** operational and design disciplines to minimize down time, In many agencies, maintenance activities of technology components are being performed through private sector contractors. Consequently, contracting efforts must be coordinated relative to technical specifications and standards, response periods and legal and administrative procedural requirements.

Administrative/Commtity Disciplines

These disciplines play a supportive role in the overall development and implementation of an ITMS These functions while not directly involved in daily operations, design or maintenance are essential in the planning and development phase. Building support for program activities is vital to establishing funding and receiving empowerment to accomplish overall and subcomponent programs. These disciplines provide this empowerment through administrative, financial, legislative and legal resources. Involving these disciplines early and throughout program operations enables an appropriate level of program understanding to be developed that fosters timely decision making by the appropriate discipline. As program operations continue over time, it is important to keep these disciplines informed such that if modifications to program activities must occur they can be processed in a timely manner. This is especially true relative to equipment failure or emergency situations where purchasing or contracting activities must occur immediately.

Maintaining a positive image of program activities and creating a vehicle for communication to the community is essential for ongoing success of the ITMS. Developing effective relationships with newspapers, local magazines, radio and television stations can be one of the best actions undertaken by an ITMS. This relationship produces positive benefits in both directions. The media can receive news worthy information relative to traffic conditions and programs that their audience desires. This is especially true for real time travel/parking conditions and corresponding video. The public sector on the other hand is able to disseminate this travel information to users in a timely manner such that travel demand can be modified and congestion conditions improved. Agencies also have the ability to effectively communicate with the public relative to new programs that are being developed and accelerate their acceptance by users.

Role of Disciplines

The development of an ITMS encompasses a range of project actives that typically includes phases associated with planning, design/construction, ongoing operations and maintenance. For each of these phases a varying combination of disciplines must be identified and brought together. Table 2 identifies a possible breakdown of disciplines by program activities. Participation by disciplines will occur at varying levels within designated phases depending upon the nature of the program activity and phase. The combination of disciplines will vary by program activity with one or more disciplines being the predominate contributors. The important concept to pursue is that numerous disciplines must be brought together during all relevant phases to ensure an effective end product. Whether it is planning, operating or maintaining a system or procedure, a team approach is necessary. Disciplines can and should complement one another in each phase with the skill and trust developed in one phase, transferring to another.

CONCLUSION

The development of an ITMS is a complex undertaking that requires the inclusion and coordination of various diverse disciplines. To achieve the intended goals of an ITMS it is necessary to identify and include disciplines that comprise both technical and non technical expertise. While it is beyond the scope of this paper to identify the combinations of disciplines for each function under taken by a TMC, the list of disciplines and their interaction between one another provide a starting point to initiate an operational needs analysis. Determining specifically what disciplines to bring together and how to accomplish this will vary by community. The key element is to develop reasonable expectations through the accomplishment of meaningful tasks that build trust and cooperative team work. Recognizing the needs and resources within each discipline and allowing those elements to be used productively will create a justification and desire for disciplines to work together.

TABLE 1. ITMS DISCIPLINES

TECHNICAL DISCIPLINES	ONGOING OPERATIONAL DISCIPLINES	ADMINISTRATIVE/ COMMUNITY DISCIPLINES
• DESIGNERS- ROADWAY/TRAFFIC	• TRAFFIC OPERATIONS	• POLITICAL LEADERS
• ELECTRICAL	• TRANSIT DISPATCH	• CIVIC LEADERS
• COMMUNICATIONS	• LAW ENFORCEMENT	• BUSINESS LEADERS
• VIDEO	• FIRE / EMS	• AGENCY MANAGEMENT
• SYSTEMS INTEGRATION	• EMERGENCY PREPAREDNESS- OPERATIONS	• AGENCY FINANCIAL MANAGEMENT
• COMPUTER HARDWARE\SOFTWARE	• FIELD MAINTENANCE FORCES-PUBLIC & PRIVATE	• AGENCY LEGAL COUNCIL
• MECHANICAL ENGINEERING	• WRECRER SERVICES	• MEDIA GROUPS- NEWSPAPERS/TV/RADIO
	• TRAFFIC REPORTING SERVICES (TRAVELER INFORMATION SYSTEMS)	
	• EQUIPMENT RENTAL AGENCIES	
	• PARKING MGT- PARKING GARAGE & LOT MANAGERS	

TABLE 2. ITMS DISCIPLINES BY TMC DEVELOPMENT PHASE

Disciplines	TMC Development Phase			
	Planning	Design	Operations	Maintenance
TECEINICAL				
Designers-Roadway/Traffic	■	■		■
Electrical	■	■		■
Communications	■	■		■
Video	■	■		■
Systems Integration	■	■		■
Computer-Hardware\software	■	■		■
Mechanical Engineering	■	■		■
ONGOING OPERATIONAL DISCIPLINES				
Traffic Operations	●	■	■	■
Transit Dispatch	■	■	■	
Law Enforcement	■	■	■	
Fire / EMS	■	■	■	
Emergency Preparedness/Operations	■		■	
Field Maintenance Forces - Public & Private	■	■	■	■
Wrecker Services	■		■	
Traffic Reporting Services (Traveler Information Sys)	■		■	
Equipment Rental Agencies	■		■	
Parking Management Parking Garage & Lot Managers	■		■	
ADMINISTRATIVE/COMMUNITY DISCIPLINES				
Political Leaders	■		■	
Civic Leaders	■			
Business Leaders	■			
Agency Management	■		■	
Agency Financial Management	■			
Agency Legal Council	■		■	
Media Groups-Newspapers/TV/Radio	■		■	

MULTIMODAL ITMS: FROM INTEGRATED TRAFFIC MANAGEMENT TO INTEGRATED TRANSPORTATION MANAGEMENT

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INTRODUCTION

Planning, designing, and operating integrated transportation management systems (ITMS) is a complex undertaking involving multiple agencies and jurisdictions. In order to respond to the numerous transportation and environmental issues facing metropolitan areas today, these systems are being designed and developed to include not only the traditional traffic and roadway management functions, but also provisions for emergency services, transit and other high-occupancy vehicles, as well as supporting travel demand management (TDM) strategies. While these functions address many of the modes currently operating in urban environments, they do not include all of the transportation components critical to the movement of both people and goods necessary to maintain the economic health and vitality of metropolitan areas. For ITMS to be a truly integrated system, and to move from a focus primarily on traffic management to a more global view of transportation management, consideration must be given to the inclusion of other modes and functions. These include toll facilities, bicycle and pedestrian systems, commercial vehicles and private operators, parking facilities, disaster response teams, railroads, and land-side access to ferries, airports, ports, and railroads. It is only through the incorporation of these modes and functions that a truly integrated system will emerge.

The integration of these modes and functions into ITMS is not an easy process, however. Numerous technical and institutional issues will need to be addressed to help ensure that these systems are developed and operated with a multimodal focus. This resource paper is intended to help foster, enhance, and expand on the discussion of the components to be included in multimodal integrated transportation management systems, potential issues and opportunities associated with this approach, and possible implementation strategies. As such, it builds on the experiences with existing transportation management systems, the previous ITMS Symposium sponsored by the Transportation Research Board (l), and the activities of other groups. It takes a fresh look, however, at the modes and functions necessary to help ensure the development and operation of multimodal ITMS to meet the complex transportation needs in metropolitan areas.

To accomplish this objective, the paper is divided into four sections following this introduction. The next section presents the concept of a multimodal ITMS and describes the various components to be included in such a system. This is followed by a discussion of potential technical and institutional issues that may emerge in planning, designing, funding, and operating multimodal ITMS. Opportunities for incorporating a multimodal focus into ITMS are also described. The next section outlines different implementation strategies that may be considered for multimodal ITMS. The approaches discussed provide for different levels of involvement, coordination, and control by the agencies and groups involved in multimodal ITMS. The paper concludes with a summary of the major topics covered and the identification of areas for further research. Examples of current applications and suggestions for possible approaches are provided throughout the paper.

THE MULTIMODAL ITMS CONCEPT AND COMPONENTS

The Multimodal ITMS Concept

A number of terms have been used over the last 25 years to describe traffic management systems and centers. The first systems developed in the 1960s and 1970s focused primarily on monitoring and managing traffic conditions on freeways. The intent of these systems was to increase the roadway capacity, increase travel speeds, reduce accidents, and improve air quality levels (2). Most of the systems initiated in the 1960s, 1970s and early 1980s-including those in Chicago, Minneapolis-St. Paul, Seattle, Los Angeles, and Northern Virginia-used the general terminology of traffic management systems and centers (TMS and TMC).

Over the years, existing and new transportation management systems have become much more complex and sophisticated. Intelligent transportation systems (ITS) and other advanced technologies are being used to expand the monitoring, detection, and response capabilities of these systems. Further, some systems encompass not only freeways, but also entrance ramps and adjacent roadways. The focus of transportation management systems has also been expanded in some cases to include other modes, such as transit and emergency services. The current terms used to describe these systems include advanced transportation management systems (ATMS) and integrated traffic management systems (ITMS) .

A number of elements are key to defining ATMS and ITMS. The intent of both is to maximize the productivity and efficiency of the surface transportation system through better management of the existing infrastructure, while at the same time enhancing safety, mobility, accessibility, and the environment. The use of ITS and other advanced technologies is critical to accomplishing these goals. The inclusion of all surface transportation modes and functions is also crucial. These include not only the freeway and roadway system that has been the focus of most existing systems, but also toll, bicycle, pedestrian, transit, HOV, and parking facilities; TDM; commercial vehicles; disaster response teams; railroads; and land-side access to ferries, airports, ports, and railroads.

Multimodal ITMS Components

Figure 1 illustrates the various components that should be considered in a multimodal integrated transportation management system. ITMS should encompass the freeway network, the arterial street system, toll facilities, HOV lanes, transit operations and facilities, bicycle lanes, pedestrian paths, parking facilities, and railroads. ITMS should also facilitate incident detection and management, emergency services, special event management, TDM, disaster response teams, commercial vehicles and private carriers, and access to ferries, airports, ports, and railroads. Many of these elements are interdependent or overlapping. Each of these components is briefly described next. Examples are provided where these elements have been incorporated into current systems and suggestions on potential applications are identified. The examples are not intended to be all encompassing. Rather, they are provided to illustrate the scope of existing and future approaches.

The Freeway Network

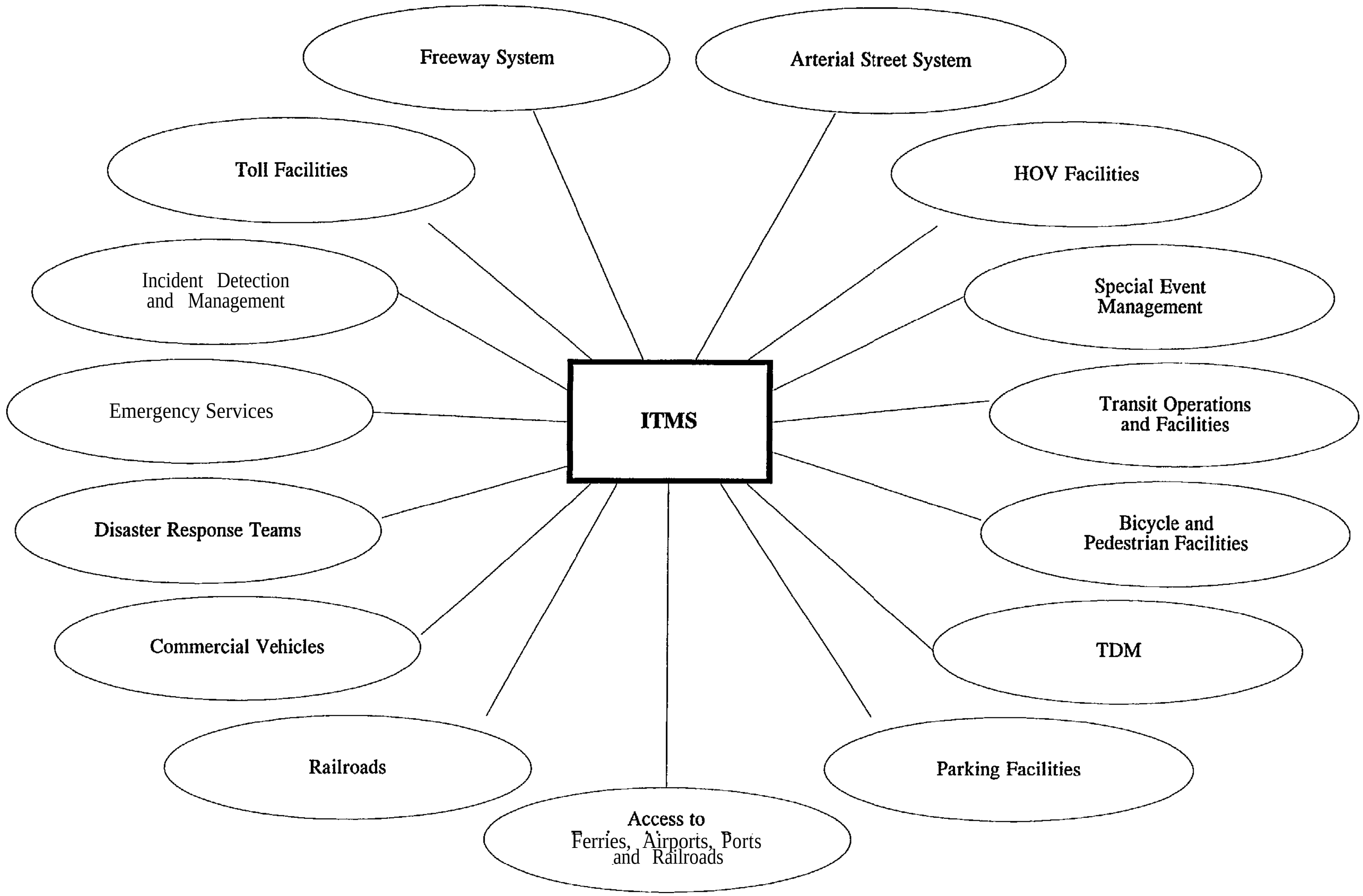
The historic focus of most transportation management systems has been on monitoring and managing the freeway network. This has included surveillance of the freeway main lanes, entrance ramps and ramp meters, and freeway-to-freeway connections. In many metropolitan areas, these systems were initiated in one or two heavily congested freeway corridors and then expanded to encompass most or all of the freeway network. A wide range of technologies are currently used to monitor and manage traffic conditions on freeways. These include loop detectors, closed circuit televisions, video imaging, changeable message signs, highway advisory radio, and other advanced technologies.

Freeway traffic management systems are in operation or under development in most of the major metropolitan areas in the United States and Canada (1,3). Further, similar systems are in use or in the planning stages in many cities in Europe and other parts of the world (4). The benefits from freeway traffic management systems have been well documented. For example, the traffic management system on I-35W in Minneapolis resulted in a 35 percent increase in peak-period speeds and a 38 percent reduction in peak-period accidents (5).

The Arterial Street System

As noted above, most transportation management systems have focused on the freeway network in major metropolitan areas. Less emphasis has been given to including arterial streets in these systems. Examples do exist, however, of the incorporation of adjacent streets and other arterials into transportation management systems. One of these is the transportation management system for the SMART Corridor Project in the Santa Monica Freeway Corridor in Los Angeles, which includes both the freeway and five parallel arterials. Further, the system under development in Orange County, California, will encompass both the freeway and the super street network (1).

Figure 1. Multimodal Components in ITMS



Ensuring that ITMS cover both freeways and major arterials will be important in the future as travel demand continues to grow. Since conditions on one element of the roadway system will effect conditions on other components, ITMS should encompass all major roadway segments in a metropolitan area, This will be especially important as more sophisticated ITS technologies and route diversion/management strategies are employed. These techniques will not be successful if traffic congestion is simply moved from one facility to another. Coordinating arterial traffic signals represents an important element of this integration.

Toll Facilities

Toll facilities-including roads, bridges, and tunnels-represent critical components of the transportation system in many metropolitan areas. Currently, toll facilities in a few areas are covered by transportation management systems. These include the San Francisco-Oakland Bay Bridge and the New Jersey Turnpike. In addition, the transportation management system under development in the Houston area will include the Hardy and Sam Houston toll roads.

Like the arterial street network, it is important that toll roads, bridges, and tunnels be included in ITMS. Given that these facilities provide critical links for the movement of both people and goods in many urban areas, it is appropriate that incident detection and management capabilities be provided. In addition, toll facilities may be integral components for diversion and other management strategies. Further, many toll facilities are utilizing electronic toll collection (ETC). Liig ETC systems into ITMS could provide additional benefits to both the toll facilities and to the ITMS.

Incident Detection and Management

A major traditional function of ITMS is the detection and management of incidents and accidents on the roadway system. The early detection and response to incidents can have a significant impact on maintaining the integrity of the roadway system. It has been estimated that every minute au accident blocks a freeway results in ten minutes of delay for oncoming traffic. Identifying that an accident or incident has occurred, dispatching the appropriate emergency or wrecking services, and taking a proactive approach to managing traffic will continue to be major fimctions for ITMS on all elements and for all modes of the surface transportation system.

Emergency Services

Emergency services play a critical role in responding to the incidents and accidents detected through ITMS. Police, highway patrols, emergency medical services (EMS), highway helper programs, and wrecker services are all used in different areas to clear accidents and to help address medical needs. In some cases, these services are notified or dispatched by the transportation management center. In keeping with the current focus of transportation management systems, emergency services usually deal only with incidents on the freeway or major roadway system.

A broader perspective is needed for the inclusion of emergency services into ITMS. This vision should build on the current role described above, but should be expanded to encompass interactive links to police, fire, EMS, and other emergency services. For example, emergency services responding to a problem not associated with the roadway system would benefit from knowing that an incident or accident is blocking the normal travel route. Providing information on the fastest and least congested travel path could mean the difference between life and death in many situations. As discussed later, adding information on the status of railroad grade crossings could also be critical to emergency services in many areas.

Special Event Management

Existing systems have been used to help manage transportation during special events. These include major one-time only events such as the 1984 Olympics in Los Angeles and the 1992 Olympic Sports Festival in the Minneapolis-St. Paul area. Coordinating and managing transportation for the 1996 Olympics in Atlanta is also being planned as part of the Atlanta Transportation Management Center currently under development. Further, existing systems are being used to help manage ongoing events, such as college and professional sporting events. For example, the Houston system is used to help with events at the Astrodome, the TMC in Minneapolis assists with traffic management for the Metrodome, and systems in Orange County and Anaheim help manage traffic for Anaheim Stadium and the many attractions in the area.

ITMS represents the logical focal point for managing all of the transportation demands for special events. A truly integrated system could coordinate and manage automobile traffic, regular transit services and special shuttle services, on-site and remote parking facilities, bicycle and pedestrian traffic, and emergency services. Further, ITMS in conjunction with special lanes and facilities, could be used to give priority to HOVs. This approach could help encourage greater use of these modes to further reduce traffic congestion.

HOV Facilities

Currently, some 52 HOV facilities are in operation in 22 metropolitan areas in North America (6). HOV lanes represent one approach being used in these areas to increase the person-movement, rather than vehicle-movement, capacity of congested travel corridors. A number of these facilities are included in existing transportation management systems. For example, HOV lanes on freeways in Houston, Minneapolis, Seattle, San Francisco, Los Angeles, Orange County, San Diego, and the Northern Virginia/Washington D.C. area are covered by transportation management systems. In addition, HOV by-pass ramps at freeway entrances are monitored on some of these facilities. In all of these cases, the same types of surveillance, incident detection, and response capabilities provided for the general-purpose freeway lanes are also provided on the HOV facilities.

Including HOV facilities in ITMS is logical given the important role they play in helping to manage congestion in major travel corridors. HOV lanes also represent a vital component of incident management, response, and diversion strategies. Further, ITMS should be expanded to cover not only freeway HOV facilities, as noted in the above examples, but also HOV lanes in separate rights-of-way and on arterial street. This will assist in maximizing the efficiency of the existing surface transportation system. Consideration should also be given to management techniques that maintain and enhance the integrity of HOV facilities and techniques to encourage greater utilization of all types of HOVs.

Transit Operations and Facilities

A few examples exist of the inclusion of transit services and facilities into transportation management systems. The HOV facilities described previously provide one illustration of this. In some cases, such as the El Monte Busway in Los Angeles and the I-394 HOV lanes in Minneapolis, the surveillance and monitoring activities extend to park-and-ride lots and transit stations. The role and participation of transit agencies in transportation management systems and ITMS has been, and continues to be, mixed, however. Historically, transportation management systems have been planned, designed, and operated by state departments of transportation or other highway agencies. Transit agencies have often had little or no involvement.

This trend seems to be changing, however, and there are recent examples of transit agencies actively participating in planning and operating transportation management systems. The Metropolitan Transit Authority of Harris County (METRO) is taking the lead, in cooperation with the Texas Department of Transportation (TxDOT), in the design and construction of the new Greater Houston Traffic and Emergency Management Center. In San Antonio, VIA Metropolitan Transit Authority plans to locate their dispatching functions in TxDOT's new advanced traffic management center. The ATMS being developed by the Montgomery County Department of Transportation will incorporate transit dispatching and operations (7). The transportation management system in Seattle also includes links to Ring County Metro.

Incorporating additional transit functions into ITMS represents a critical component of a multimodal focus. Transit systems can benefit from this integration through real-time information on roadway conditions, travel times, and incidents and accidents. Transit vehicles can then be diverted around trouble spots, improving on-time performance, schedule adherence, and service efficiency. Transit vehicles equipped with automatic vehicle location (AVL) systems may also be able to act as traffic probes, providing information on traffic conditions on arterial streets and freeways to the ITMS. Approaches to integrating transit into ATMS are being explored as part of the ITS Research Center of Excellence at Texas A&M University.

Bicycle and Pedestrian Facilities

Only a limited number of examples exist of bicycle or pedestrian facilities being integrated into ITMS. The pedestrian and bicycle paths on the I-90 tunnels in Seattle are monitored by the Washington State Department of Transportation TSMC. In Minneapolis, the pedestrian bridge across I-94 linking the Walker Sculpture Garden with Loring Park is monitored by the Minnesota Department of Transportation (Mn/DOT) transportation management center, Given the growing interest in many areas in the use of bicycle and pedestrian projects to serve both commute and recreational trips, it is appropriate to include them in ITMS. The nature and extent of this coverage should be matched to the facilities, climate, and geography of different areas. For example, including the skywalk and tunnel systems found in many downtown areas into ITMS may be a logical connection, especially where these systems are used to help distribute passengers from transit services or remote parking facilities. Further, including bicycle and pedestrian paths in ITMS would greatly enhance the safety and security of these facilities.

Travel Demand Management Programs

Travel Demand Management (TDM) and Transportation Control Measures (TCMs) are being planned and implemented in many areas to address concerns over increasing traffic congestion, declining mobility, and environmental concerns, as well as to respond to specific requirements of the Clean Air Act Amendments of 1990. TDM and TCM programs focus on increasing the use of HOVs, spreading travel into less congested time periods, and removing trips all together from the transportation system. Coordinating these activities with transportation management systems and incorporating them into ITMS will be critical to their success. This process has already begun in some areas. For example, providing by-pass lanes for HOVs at freeway entrance ramps and initiating express buses on the freeway were major components of the initial traffic management system on I-35W in Minneapolis. There appear to be numerous opportunities to expand the coordination between TDM/TCM programs and ITMS, however. Fully incorporating TDM/TCM programs into ITMS represents a critical component to the multimodal focus and the ability to address the traffic, mobility, and environmental concerns in metropolitan areas.

Parking Facilities

Currently, parking lots and parking garages are not covered in most transportation management systems in the United States, although examples do exist in Europe. The few exceptions to this focus on park-and-ride lots associated with freeway HOV lanes. In some cases, surveillance is provided at these facilities and at adjacent transit centers. Further, the direct access connections provided from the I-394 HOV lanes into the parking garages on the edge of downtown Minneapolis are monitored as part of the Mn/DOT transportation management center.

Parking lots and garages should be incorporated more extensively into ITMS, however, based the importance of these facilities to commuters and travelers. The inclusion of parking lots and garages in ITMS would have a number of benefits. First, the monitoring and surveillance of these facilities would enhance the safety and security of users. Second, real-time information on the availability of spaces, as is done in some European cities, could be provided to travelers well in advance of the different facilities. This would help reduce the need for drivers to circle looking for parking and would reduce air pollution generated from these activities. Including parking facilities in ITMS would also assist with special event management and could be used to support TDM and TCM programs focused on providing discounted parking rates or preferential parking locations for HOVs.

Disaster Response Teams

Transportation management systems have played important roles in helping to respond to major disasters. Two recent examples are the use of the systems and control centers in Los Angeles and San Francisco to coordinate the response to the damage caused by major earthquakes. Incorporating the ability to accommodate disaster response teams into ITMS should be considered in all areas. This is especially critical, however, in those areas susceptible to natural and man-made disasters. These include areas prone to earthquakes, hurricanes, tornados, flooding, and major snow storms. Further, areas with high risk industries or facilities, such as petrochemical plants, pipelines, nuclear power plants, and hazardous wastes, should consider the need for disaster response teams in the ITMS center. ITMS represents the logical approach to coordinated traffic management, evacuation, emergency services, and other functions necessary to respond to natural and man-made disasters.

Commercial Vehicles and Private Operators

Existing transportation management systems monitor commercial vehicles as part of the general traffic flow. Special services or additional activities focused on commercial operators are not provided in most cases, however. A number of approaches could be used to integrate commercial vehicles more fully into ITMS, benefiting all groups. For example, providing real-time information on traffic conditions to commercial operators could help in planning travel routes and schedules. Coordinating the permitting and state inspection processes with ITMS may also be possible. Many of the ITS Commercial Vehicle Operation (CVO) applications focus on improving the permitting process among the different states. ITMS could help facilitate these activities. Commercial vehicles could also act as traffic probes, providing information on conditions on the roadway system. Finally, as discussed in more detail in the last element in this section, specific information could be provided to commercial vehicles accessing major intermodal facilities, such as ports, airports, and railroads.

Railroads

Railroads operate in most urban areas, providing an important means for transporting commodities and people. To date, railroads have not been included in traffic management systems. There are a number of reasons why railroads should be included in ITMS. First, although railroads operate in exclusive rights-of-way, at-grade railroad crossings are found in many areas. The movement of trains through these at-grade crossings can have a significant impact on traffic, especially during peak-periods. Second, the potential for accidents involving automobiles, buses, commercial vehicles, and trains exists at any crossing. Third, derailments or other problems may occur along rail lines. These situations may be further complicated if noxious or hazardous materials are being transported by the railroads.

As a result, railroads should be incorporated into multimodal ITMS. Coordinating ITMS and the advanced train control systems (ATCS) operated by many railroads could benefit numerous groups. Better managing the timing of trains with other element of the surface transportation would benefit the traveling public. For example, the railroad lines located adjacent to the I-10 West Freeway in Houston significantly impact traffic in the corridor. Enhancing coordination among the railroad, the local street and signal system, and the freeway would enhance trave1 in the corridor. The safety of motorist, the railroads, and residents in the area could also be enhanced. Possible approaches to integrating railroads into ATMS are being examined in one of the research projects being conducted by the ITS Research Center of Excellence at Texas A&M University.

Access to Ferries, Airports, Ports, and Railroads

As discussed previously, ITMS could play an important role in managing the access to ferries, airports, ports, and railroad terminals by both commercial operators and the general public. Providing real-time information on the status of roadways leading to these facilities is an obvious approach that would have significant benefits to all groups. This could include providing information on travel times, travel speeds, and alternate routes. To be effective, however, a two way flow of information is needed. This would involve providing information on the status of operations at these facilities to the appropriate groups. For example, truckers could better manage their schedules if they were aware of delays or long lines to unload or load their cargo at a port facility. Further, travelers could be informed if ferry or airplane arrivals and departures have been delayed due to weather or other situations, relieving anxiety about missing corrections .

POTENTIAL TECHNICAL AND INSTITUTIONAL ISSUES WITH MULTIMODAL ITMS

A number of issues may be associated with planning, designing, funding, and operating a multimodal ITMS which incorporates all of the modes and functions described previously. In general, the types of issues which might be encountered can be divided into two groups; those that deal with technical concerns and those focused on institutional problems. Technical issues can be further categorized into the system architecture requirements and the technologies utilized by different groups, functional integration, and location and communication. Agency roles and responsibilities, funding, and legal issues represent some of the more important institutional issues which might be encountered. Each of these issues is described briefly in this section, along with approaches and opportunities that might help overcome them. Although many of these issues are similar to those involved with the development of any transportation management system or related project, the multimodal focus of ITMS adds complexity and may make it more difficult to resolve some problems.

Technical Issues

A wide range of technologies are being utilized in existing transportation management systems. These include loop detectors, closed circuit television, video imaging, changeable message signs, highway advisory radio, and other technologies. Further, research and development activities, operational tests, and early deployment projects are focusing on the use of ITS and other advanced technologies to enhance the incident detection and response capabilities, as well as the information sharing capabilities, of ATMS. The key technical issues which may be encountered in planning, designing, and operating a multimodal ITMS are described next.

System Architecture Requirements and Technologies Utilized

A variety of technologies are being used in existing transportation management systems and additional advanced technologies are being developed and tested. New technologies are also being utilized with the other modes described previously. For example, many transit agencies are implementing automatic vehicle location (AVL) systems to help monitor the location of buses. Advanced train control systems (ATCS) are used by railroads for similar train location functions. Police, fire, and EMS also use a wide range of technologies to support their functions.

Ensuring that the technologies utilized by the different modes and groups are compatible will be critical to realizing the goal of a multimodal ITMS. Developing a system architecture that will incorporate all of these modes and functions can help in this effort. A system architecture provides a framework that identifies how the various system components interact and work together to achieve the overall goals of the project. It describes the operation of the system, the functions of each component, the information exchange between the various components, and helps to identify the need for critical standards (8). A process is currently underway to develop a national ITS system architecture. This effort, which is being funded by the United States Department of Transportation, should help address many of the potential technology issues associated with the development of a multimodal ITMS.

System Design and Functional Integration

Even with the adoption of a common system architecture, additional steps will still be needed to develop the design of a specific ITMS and to integrate all of the necessary functions for the different modes. Thus, a number of issues will need to be addressed with the system design and functional integration of a multimodal ITMS. Elements that may need to be examined include the integration of different technologies, designing decision support systems, modeling and simulation capabilities, database development and management, software design and development, and data and system reliability. The issues and opportunities associated with system design and functional integration may be different in those areas with existing ITMS and those developing new systems.

Location and Communication

The last major technical issue area relates to the actual location of the different components of the system and the communication links between the various modes and elements of an ITMS. Establishing the communication network and the links among the different functions and organizations represent critical elements in the development of an ITMS. Issues may arise over the compatibility of technologies used by different modes, information processing procedures, and system reliability. Communication technologies are evolving rapidly and ensuring that the appropriate technologies are utilized will be important.

Further, the issue of location will need to be addressed. A number of alternative location scenarios could be employed. For example, a central control facility could be used, with all the modes and functions located in the same building. Another option would be to utilize multiple sites, with information and control shared through the use of advanced communication networks. Various combinations of these alternatives could also be utilized, with both a central control center and communication links into individual agencies at remote locations.

Institutional Issues

Institutional issues have been identified as potential impediments with many types of programs, including transportation projects. For example, institutional issues associated with transit joint development projects (9), HOV facilities (10), and ITS operational tests (11) have all been documented. It has often been suggested that the institutional issues associated with these and other projects are more difficult to address and overcome than the technical issues. Three of the major institutional issues that may be encountered with a multimodal ITMS are described next. Possible approaches for address these concerns are also outlined.

Agency Roles and Responsibilities

The development and operation of an ITMS which incorporates all of the modes and functions described in this paper will require the involvement of numerous public agencies and private businesses. Coordinating the activities of these diverse groups will not be an easy process. Numerous issues may emerge relating to the roles and responsibilities of the different public and private organizations. In many cases, simply reaching an agreement to develop a multimodal ITMS will be a major accomplishment. Other potential issues include sorting out the responsibilities of the different groups, establishing working relationships among organizations that have not worked together before, selecting a lead agency and project manager, establishing a process for resolving conflicts, and coordinating the activities of the various agencies and businesses.

The sheer number of agencies and organizations that need to be involved in a multimodal ITMS may represent a major challenge. Historically, state departments of transportation have been responsible for the development and operation of most transportation management systems. Other groups, such as transit agencies, police, and other emergency services, have become more involved recently in many areas. The inclusion of the modes and functions illustrated in Figure 1 will necessitate the involvement of even more public agencies and private groups. These may include toll authorities, railroads, airports, ports, commercial operators, local governments, police, fire, EMS, state and national disaster relief agencies, parking authorities and private parking facilities, special event organizers, and park agencies.

Getting these groups to work together and obtaining agreement on a common approach represent issues that may be encountered very early in the planning process. Thus, establishing the roles and responsibilities of the different groups represents a critical step. This can be difficult even with groups that have traditionally worked together, which is not the case with most of the organizations noted above. The mix of public and private groups makes the situation even more complex. Agencies may use different procedures, and the organizational cultures may vary greatly. Further, uncertainty or mistrust may exist among various groups. Overcoming these concerns will be a critical step in the development of a multimodal ITMS.

Issues may also arise in the selection of a lead agency and a project manager. Although multiple groups will need to be involved for ITMS to be successful, most projects have one agency or group with overall responsibility. Studies of other transportation improvements have pointed out the importance of both a lead agency and a strong project manager. As noted previously, the state department of transportation has usually taken the lead in the development of existing transportation management systems. They may also be the appropriate lead agency in a multimodal ITMS. Creating a new organization, charged only with developing and operating the ITMS, represents another possible approach. Still another approach is to establish a multi-agency group, charged with coordinating the activities of all groups. The use of combinations of these different approaches is also possible.

Studies of HOV facilities and ITS operational tests have also pointed out the importance of support from top management and having a project champion to the success of a project (10,ll) Strong and visible support from the top management of all organizations will be critical to the success of a multimodal ITMS. In addition, a project champion can greatly enhance the success of any venture, including ITMS. Key characteristics for a project champion, which may be either an individual or a small group, include being in a position of authority, an ability to influence the process, being respected by others, and a willingness to take risks. The development of a multimodal ITMS provides the opportunity to maximize the resources of all groups.

Funding

Obtaining adequate funding for any transportation project is often a major concern. Most significant highway and transit projects are funded through a combination of federal, state, and local funds. Identifying potential funding sources, developing a financing plan, obtaining necessary approvals, securing the funds, and carrying out the financing program, represent major steps associated with any project. These steps are not easy even with relatively simple projects and become even more complex with a multimodal ITMS.

For example, the multiple agencies and groups described previously may all be participating in funding. The multiple funding sources available for ITMS provides a real opportunity. The mixing of funds from multiple federal, state, and local agencies may result in a complex grant application process, however, and may complicate grants management. Adding private funding sources to this mix may further complicate the situation. Developing a financing plan for a multimodal ITMS will require not only special skills, but also the close cooperation and coordination of the various groups involved.

The increased complexity of the financing approach needed for a multimodal ITMS may lengthen the project development and project implementation time periods. For example, funding and application cycles may differ between various programs and agencies. Obtaining approvals from the multiple federal, state, and local agencies involved in ITMS may require more time than if just one or two agencies were involved. Adding private funding sources into this may further lengthen the time needed to secure the financing needed for a multimodal ITMS.

Although the involvement of multiple public sector agencies and private businesses adds to the complexity of funding a multimodal ITMS, it also creates a number of opportunities. For example, it may be possible to spread the costs associated with the development and operation of the ITMS out among more groups, lessening the financial burden to any one agency. Further, the numerous groups involved increases the opportunity to leverage funding from multiple sources. Private funds may be used to match public funding, increasing the total amount available for the project.

Recent activities at the federal level may afford further opportunities. The Intermodal Transportation Surface Efficiency Act (ISTEA) of 1991 provides new programs for funding ITS, including those related to ATMS and ITMS, and allows greater flexibility in the use of different program funds to respond to locally identified needs. The ISTEA established a new research program to promote the development and deployment of ITS and other advanced technologies. Numerous activities related to ITS are underway through the coordinated efforts of federal, state, and local agencies, private businesses, national laboratory, university research institutes, and other groups. These efforts, as well as the increased flexibility offered by the ISTEA, may provide numerous opportunities for areas interested in developing multimodal ITMS .

Legal

A number of legal issues may need to be addressed in the development and operation of multimodal ITMS. Potential legal issues include ensuring that agencies posses the necessary authority to implement the various provision of ITMS, liability and insurance questions, and privacy concerns. Each of these represent complex issues which should be examined early in the planning process.

The various agencies responsible for planning, designing, funding, constructing, and operating a multimodal ITMS must have the legal authority to undertake all the necessary functions and activities. These may include the ability to enter into interagency agreements and contracts with private business, purchase property and equipment, construct and maintain buildings and equipment, and own and operate the various elements of the ITMS. The diverse public and private sector groups involved in a multimodal ITMS adds to the complexity of accomplishing all of these functions. Changes in enabling legislation or other laws may be necessary to allow different agencies and organizations to fulfill all of these activities.

In order to address many of these concerns, some areas have established new organizations charged with the responsibility of planning and operating ITMS. Two examples of this approach are the Greater Houston Traffic and Emergency Management Center and TRANSCOM in the New York and New Jersey area. More information on the approaches used in these areas are provided in other resources papers.

Other potential legal issues relate to liability and insurance concerns. Problems in these areas may arise in response to actions taken by individuals in response to the information provided by the ITMS. For example, liability and insurance issues may arise if there is an accident or property damage resulting from traffic being diverted from a freeway onto an arterial street. In another possible example, liability concerns may arise in the routing of emergency vehicles if the response time is deemed not fast enough by an injured party.

A last major legal issue that may arise relates to privacy. ITMS will be able to monitor and track a wide range of information, including the location of private automobiles, and thus individuals. How this information is used, especially related to police and law enforcement activities as well as situations that individuals may feel invade their privacy, will need to be addressed.

ALTERNATIVE IMPLEMENTATION STRATEGIES

There are a number of approaches that may be used to plan, design, implement, and operate a multimodal ITMS. Examples of some of these techniques are being examined in more detail in other resource papers. Possible approaches include expanding the roles and functions of existing transportation management systems, utilizing an existing agency to lead the development of a multimodal ITMS, establishing agency partnerships with shared funding and management responsibilities, and creating a new organization charged with the same responsibility. In addition, a multimodal ITMS could be organized in a variety of ways. For example, all of the modes and responsible agencies could be located in the same building or control center. Under another possible organizational scenario, they may be physically located in different areas, but may share information and communicate through a variety of advanced technologies.

Regardless of the exact organizational structure used, there seem to be at least three basic levels that are appropriate for consideration in the development of a multimodal ITMS. These levels relate to the sharing of information, facilities and equipment, and control. Each of these represents a step toward greater integration, with the last level representing a truly multimodal ITMS.

The first level focuses on the sharing of information and data among the various modes and organizations involved in a multimodal ITMS. In this situation, the decision on how to react to the real-time traffic information and the specific actions which might be initiated in response to an incident would be left up to the individual entities. At the second level, the different organizations would share information, as well as facilities and equipment. This represents a step along the continuum toward greater integration.

Finally, at the last level, the various organizations would share not only information and facilities, but also control. In this scenario, specific actions could be initiated by different agencies in response to pre-agreed upon plans and decision support systems. Thus, control over different elements of the transportation system would be shared among the agencies. Accomplishing this sharing of control will not be an easy process, however, as it will require some agencies to share their historic responsibilities. The institutional issues discussed previously will need to be addressed to accomplish this last step.

CONCLUSIONS

This paper has examined the modes and functions to be incorporated into multimodal ITMS . It has provided a discussion of the multimodal ITMS concept and the various components to be included in such a system. Potential technical and institutional issues that might be encountered in the development and operation of a multimodal ITMS were described, and alternative implementation strategies were presented.

A number of areas will need to be examined in more detail to help advance the development and operation of multimodal ITMS. Additional research examining the technical and institutional issues identified in this paper would be beneficial in fostering the deployment of ITMS. For example, further research is needed on the development of a common system architecture, as well as examining the issues associated with the design and functional integration of a specific ITMS. Designing the decision support systems, communication protocols, and control strategies, represent other areas where further research is needed.

A number of institutional issues should also be examined in more detail. Identifying approaches to overcome potential liability and other legal concerns will be critical, as will developing innovative partnerships among public and private sector groups. The successful deployment of a multimodal ITMS will require changes in‘the traditional roles and responsibilities of public agencies and private operators. Change is never an easy process, and identifying approaches to help overcome potential concerns would be valuable.

Although not examined in this paper, public acceptance will be an important factor in the ultimate success of multimodal ITMS. Additional research on public attitudes toward advanced technologies, real-time information, incident diversion strategies, and privacy would be beneficial in the design of ITMS. Examining the human factors issues associated with the operation and use of the different components of a multimodal ITMS would also be of benefit.

As discussed in this paper, the design, development, and operation of a multimodal ITMS will not be an easy process. Numerous opportunities exist, however, and possible technical and institutional issues can be addressed. The potential benefits of a multimodal ITMS are well worth the time and effort spent resolving these concerns, however. Incorporating all of the modes and functions discussed in this paper into a multimodal ITMS will assist in ensuring the continued vitality and economic health of metropolitan areas throughout the country.

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INTEGRATED TRANSPORTATION MANAGEMENT SYSTEMS ENVIRONMENTAL CONSIDERATIONS AND ISSUES

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INTRODUCTION

The Nation's transportation system has supported the economy for decades, but it has come under increasing pressure due to limited capacity, poor connections between different transportation modes, and the rapid travel growth that accompanies a robust economy. In the 1950's, with automobile use and traffic increasing rapidly as a result of the post-war boom, we initiated construction of the Interstate Highway system-the largest public works project ever, and one which linked the United States from coast to coast.

That same approach to accommodating increasing travel and traffic in the 1990's is not feasible or acceptable; we continue to experience long-term traffic increases beyond our capabilities to serve them because of our continuing growth and increasing reliance on the automobile as our primary source of mobility. Although we are still building new highways and expanding existing ones, we no longer can afford to build all the roads we might need-and even if we could afford it fmancially, we cannot afford the other impacts of such an expansion.

So we are striving to manage the transportation system more effectively and efficiently through strategies which include an increased emphasis on Integrated Transportation Management Systems (ITMS) approaches as we11 as advanced technology applications such as Intelligent Transportation Systems (ITS). And, while the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) directly authorized more than $660 Million through Title VI for Intelligent Transportation Systems (ITS), with the likelihood of very substantial expenditures of funds through other program categories, the full potential of the more sophisticated of these systems will not be realized for many years, Moreover, many of the ITS applications depend heavily on the successful implementation of ITMS, including many first generation ITS applications, which are in place or being implemented in many locations throughout the United States.

For example, tracking and transaction systems for commercial vehicles fitted with sensors and Global Positioning Systems, fully automated collection of tolls, automatic clearance of trucks at state borders, enhanced vehicles with collision avoidance systems and other safety features, and automated highway systems such as the recently announced consortium led by General Motors will not be fully operational for quite some time. Yet, integration of the various components of existing systems and modes (the underpinning of ITMS) through applications such as smart traffic signals, synchronized signal systems in major travel corridors, and traveler information systems providing real time information offers immediate and short term opportunities for ITMS to play a critical role in our ability to address congestion and environmental concerns in our urban areas. The potential of ITMS to fully integrate transit systems into traffic and highway systems is especially promising.

BACKGROUND

The results of the 1990 National Personal Transportation Survey (NPTS) (1) are revealing with respect to our increasing reliance on the automobile and the opportunities for ITMS to play a critical role in our transportation systems of the future. According to NPTS, household vehicles available from 1969 to 1990 increased 53 % and the total number of household vehicles increased at a rate of 4% per year or 128 % over the 21 year period.

The number of households which had more than one vehicle available grew from 26.4% in 1969 to 38.4% in 1990, a 117 % increase or 3.8 % per year compounded annually. Similarly, the number of households with three or more vehicles available increased from 4.6% of households in 1969 to 19.5% in 1990, an increase of 535%) a 9.2% compounded annual rate of percentage change.

Over the 1969 to 1990 period, the total number of households increased by 49% while the number of household vehicles increased by 128%. Further, from 1983 to 1990, steady decreases in household size brought more daily trips and longer trip lengths resulting in a 29% increase (3.6% compounded annually) in daily household vehicle miles travelled from 1983 to 1990.

Concurrently, the number of daily person trips increased 58% from 1969 to 1990 with the number of person trips by auto, van, and truck increasing 64% over the same time period. Alternative mode use for commuting such as transit, bicycling, walking, decreased during this same time period while an increase in driving alone for commute trips occurred.

Demographic trends also affected increased travel. For example, people over 65 drove more often and for longer trip lengths than ever before according to NPTS , resulting in an increase of 26 % in average annual person miles of travel by individuals 65 years of age or older. These trends combined with established land use patterns will lead to even more travel in coming years.

On a parallel track with these growth trends, we are realizing more and more that for a variety of reasons, we simply cannot continue to add capacity in traditional ways to our transportation system. Reasons for this include: cost and availability of land in our most congested areas, environmental concerns including noise, water, and air quality: and, importantly, a growing realization among transportation professionals and policy makers at all levels of government that building more and more lanes of capacity will never satisfy our collective desire for greater mobility. The more we build, the more we need to build. Finally, the cost of construction is prohibitive in an era when government finances are increasingly scarce and the existing maintenance and operations needs of the system cannot be met. Enormous backlogs in the maintenance and rehabilitation of our roads, bridges, and highways are commonplace in many areas in the country.

All these factors combined lead transportation professionals to the conclusion that we must concentrate our collective energies on identifying ways to better manage, maintain, and operate what we have in the most efficient manner. This challenge is a central theme of the ISTEA and is fundamental to implementing ITMS.

The Opportunities for Integrated Transportation Management Systems (ITMS)

The need for solutions to the complex array of problems which all point to more congestion also point to tremendous opportunities for the development and implementation of ITMS Yet, the delivery of such programs, from the policy, political, institutional, technical, and operational perspectives, is an enormous undertaking. And doing so in an environmentally sensitive manner is an integral part of the challenge. The tools available to assist us in this endeavor are truly extraordinary, however. Specifically, the advances in technologies available to the transportation sector to address these problems coupled with the federal governments' willingness to invest heavily in technological applications to ITMS provide a critical catalyst to bringing new technologies to market to help address truly enormous congestion and environmental problems.

How do transportation professionals meet the dual challenges to deliver ITMS programs which address the full array of environmental and congestion concerns in a cost effective manner in both the short-and-long term? This paper will discuss environmental issues related to developing and implementing ITMS for maximum efficiency and benefit of the customers.

A Broad View of Environmental Issues

Upon reflecting on events of the past few years in the transportation industry, it is clear that air quality issues have served as a catalyst to changes in the methods and analysis techniques transportation professionals use to advise public policy decisions on investments. Air quality issues and immediate concerns about compliance with transportation conformity requirements and other Clean Air Act mandates such as implementation of Transportation Control Measures (TCMs) have tended to take precedence over much larger environmental issues and challenges to successfully implementing ITMS in an environmentally sound manner In addition to the important objective of meeting the federal standards for various air borne pollutants caused by mobile sources, other environmental concerns which need to be considered include:

- reducing generation of toxic and hazardous substances,
- optimizing use of and decreasing overall consumption of energy resources and other natural resources in the transportation sector,
- advancing the cause of "environmental justice" by improving environmental and economic conditions for minorities and low income groups,
- strengthening communities, improving neighborhood livability,
- preserving historic and cultural resources, and reinvigorating central cities, and
- preserving open space, scenic vistas, agricultural land, endangered species, wetlands, habitat and water quality.

In discussing environmental considerations, a broad view of environmental issues should be taken: one which recognizes the broad array of environmental issues with which we should be concerned. Concurrently, we must take into account the realities of widespread congestion, the development patterns which have resulted in part due to our extensive highway network, and the fact that automobiles are, for the foreseeable future, going to be the primary source of mobility in this country. For even if the air quality problem can be addressed in large part through the application of various technologies (e.g., electrically heated catalysts, reformulated gasoline requirements, enhanced inspection and maintenance programs, the introduction of alternatively fueled vehicles), transportation professionals must address the irrefutable fact that ever increasing numbers of vehicles are filling up limited road space resulting in congestion levels that denigrate overall system performance. It is the concern with system performance embodied in ITMS that helps us sharpen our focus.

ISTEA requires that state and metropolitan area transportation professionals develop six Management Systems and explicitly consider twenty-three and fifteen planning factors respectively. These requirements have, as the ISTEA intended, prompted transportation professionals and policy makers to recognize the broad implications of investment decisions. These provisions have also caused us to think differently than in the past about how we design, construct and maintain efficient and environmentally friendly transportation systems. The new orientation brought about by ISTEA is that the transportation system should serve the customers needs, not that the customers should be placed at the mercy of the system. The question transportation professionals need to ask themselves on a regular basis is: are we serving the public's needs and desires by providing an efficient, well-integrated, and environmentally friendly transportation system?

Environmental Considerations in Implementing and Operating ITMS

ITMS approaches can be helpful to us in achieving our broad environmental objectives. The key to balancing our transportation needs and environmental goals through ITMS lies in the design for and application of ITMS concepts and practices. To succeed in this endeavor, environmental issues need to be carefully considered in two interrelated but distinct phases of ITMS implementation. These are the planning, project selection, and design phase on the one hand; and, on the other hand, the implementation, maintenance and operating phases.

Planning, Project Selection, and Design Phases of ITMS

The planning, project selection, and design phases of ITMS is the time to fully integrate all modal considerations into projects and programs. For example, the needs of existing or future High Occupancy Vehicle (HOV) lane access and egress need to be considered throughout these phases. Existing or future transit needs on the arterial or highway system should be addressed. Priority treatments for transit have proven, in the U.S. and abroad, to be very successful to encouraging transit use and can be effectively designed into ITMS. True multi-modal planning should consider all modes which will be or could be operating on the same or adjacent Right-of-Way (or in the same corridor) such as light rail, bicycling, rail or truck freight, and pedestrian movements.

Below are some specific suggestions for integrating ITMS into the overall transportation planning process which are in part based on the results and recommendations of a recent study by the State and Local Policy Program of the University of Minnesota's Hubert H. Humphrey Institute (2).

- Integrate ITS with on-going traffic demand management programs, livable community initiatives, and the introduction of new information technologies such as traveler information systems.
- Ensure that traffic smoothing investments are coordinated with travel demand strategies to improve the time advantage to non single-occupancy vehicle (SOV) travel.
- Provide incentives for non-SOV travel including: ramp metering by-passes, signal preemption, and preferential treatments for transit and HOV vehicles.
- Ensure priority is provided for transportation demand management strategies which promote mode shifts.
- Promote the integration of remote sensing and other emission detection strategies into ITMS technologies.
- Include representatives of stakeholder groups in project planning and program development to get their input and buy-in to the deployment plan and focal points of your ITMS program or project.
- Collect emissions and travel behavior data on ITMS projects in order to assess the true environmental impacts and mode shift effects.
- Consider future plans or prospects for traveller information systems and how the ITMS support the data needs of such systems.

These are all examples of how fully integrated ITS depends on ITMS being implemented with an eye toward the future. All parties involved with the design and selection of projects need to consult a broad array of modal interests on their plans if the ITMS system is going to properly address both current and future transportation needs and environmental considerations.

Environmental Issues in Operating and Implementing ITMS

The implementation, operating and maintenance requirements of the systems must be identified in order to ensure proper consideration of environmental impacts. The implementationof complex computer systems and equipment will not allow, in and of itself, the transportation sector to realize its full range of objectives in implementing ITMS. For example, if the objective of a system is traffic flow uninterrupted at 30 miles per hour, the system needs to be continually monitored, maintained, and properiy operated to achieve that objective. The difference from an air quality perspective, of free flow vs. stop and go congestion can be significant and implementers and maintainers of the system need common agreement on their operational objectives vis. a vis project and program delivery. This points to the need for sufficient training and anticipation of operating requirements, on-going operations monitoring, and consensus among policy makers and transportation professionals on the objectives of ITMS implementation.

One example of the complex policy trade-offs which need to be addressed relates to the recent emergence of information concerning the relationships between emissions of Nitrogen Oxides (NOx) and highway speeds. This case also illustrates the complexities of air quality chemistry and interactions among pollutant types as well as the lack of good tools for credible analysis of these interactions. Nevertheless, until better tools are available and understanding of these relationships advanced, the following issues should be considered in planning for the implementation and operations of ITMS.

NOx emissions vary considerably with speed and heavy duty trucks are a much larger source of NOx than any other type of on-road vehicles. With respect to cars, emission factors (based on EPA MOBILE5 model) decrease with increasing average speed in the range of O-15 miles per hour. Thus, at constant VMT, speed improvement strategies in extremely congested areas may yield NOx emission decreases. Emission factors gradually increase, however, with increasing average speed in the mid-speed range of 1545 miles per hour. For constant VMT in this range, speed flow improvements generally reduce VOC emissions but may increase NOx emissions. According to the MOBILE5 model, NOx emissions increase sharply with increase average speeds in the high speed range (greater than 45-50 miles per hour).

The overall impact of transportation projects on NOx emissions will depend on the project-induced changes in the VMT distribution among the various speed improvements. In order to minimize increased NOx emissions due to speed flow improvements (many of the first generation of ITMS applications) and reduce VOC emissions, one could strive to increase speeds beyond the 15 miles per hour range but attempt to hold speeds on average at no greater the 45 miles per hour. Thus, the desire to improve traffic flow through ITMS applications while reducing or having a neutral effect on emissions presents difficult trade-offs. The political and institutional will to make these trade-offs can only be decided at the local level where all variables can be taken into account. This example also illustrates that transportation professionals must be able to explain these trade-offs to decision makers when advising them on ITMS investments.

Importance of Effective Operating and Maintenance Policies

With respect to on-going maintenance and operations efforts to date, a March, 1994 GAO (3) report on the use of traffic control systems to reduce congestion revealed that in a review of 24 signal systems nationwide, the FHWA found that 21 systems (88%) did not meet the minimum standards of performance and that some localities were designing systems that were outdated or did not meet their needs. In addition, the Institute of Transportation Engineers (ITE) estimated in 1989 that 74 % of the 240,000 signalized intersections in the nation's urban areas needed upgraded physical equipment or improved signal timing. These problems are currently preventing regions from achieving the optimum results; the implications for the future may be even greater because of the reliance on these systems of the emerging ITS technologies. Interestingly, an increasing amount of federal funding is being used for traffic control systems (1991-$221 Million, 1992-$289 Million, and 1993-$503 Million) and hopefully some of these funds are being used to address problems identified in the GAO report. Since the Congestion Mitigation and Air Quality Program (CMAQ) program fundmg began in 1992, a considerable proportion of CMAQ funds have been used for ITMS investments.

Benefits **of Properly Designed, Operated and Maintained Systems**

The GAO report also confirmed that properly designed, operated, and maintained traffic control signal systems can yield significant benefits both along the corridors in which they operate and along adjacent corridors. These benefits include congestion mitigation, reductions in air pollution, reductions in accidents, fuel consumption, and travel time.

One illustration of benefits is Automated Traffic Surveillance and Control (ATSAC) System in Los Angeles where the City of Los Angeles reports that the system reduced travel time (in the areas covered by the system) by 18 % , signal delays by 44 % , vehicle stops by 41%) fuel consumption by 13 % , and air pollutants by 14%. During the aftermath of the earthquake in Los Angeles in Spring, 1994, the benefits of the system were apparent from the first day when the City and Caltrans immediately used the ability to dynamically control and synchronize signals in the Santa Monica Freeway (I-10) corridor to manage more than 434,000 person trips per day affected by the collapsed segment of the Santa Monica Freeway.

According to the GAO report, in Orlando, Florida, an analysis of a new signal system implemented in 365 intersections showed $2.2 million in fuel savings per year, a 56% drop in both vehicle stops and delays, and a 9 to 14% reduction in air pollutants. The State of Washington analyzed the benefits of upgrading and coordinating signal control equipment and re-timing existing signals for six signal systems. These studies showed annual fuel reductions of 295,500 gallons and annual reductions in vehicle delays of 145,000 hours. In Virginia, a recent study showed that re-timing several signal systems reduced delays by 25.2 % , stops by 25.5 % , travel time by 10.2 % , fuel consumption by 3.7 % , and air pollutants by 16 to 19%.

These cases demonstrate that the environmental impacts of ITMS can be beneficial: however, our data collection and analysis tools are weak and we need to better monitor, evaluate, document, and understand the impacts during implementation as well as consider the potential impacts during the planning, project selection, and concept design.

CONCLUSIONS

Many opportunities exist for ITMS to play a critical role in both short-and-long term solutions to transportation and environmental problems. Practitioners and policy makers alike must work toward a more inclusive transportation investment decision-making process however; a process which allows all parties to provide input and consider trade-offs where they exist. These enhanced interactions will allow for environmentally sound ITMS applications and new investments to be made, and for ITMS to successfully open the policy and funding doors to the more sophisticated ITS applications which are increasingly available to the transportation community. The realization of the benefits that ITMS offer as critical elements of solutions to transportation and environmental problems is dependent on the community of transportation and environmental professionals working together to provide the leadership necessary to change the old way of doing business and move on to a more environmentally proactive posture when considering transportation investments. Efforts to foster good working relationships have been initiated in many forums since the adoption of the Clean Air Act and the ISTEA. The importance of creating opportunities for transportation and environmental professionals to interact on an ongoing basis cannot be overstated. In the fmal analysis, successfully meeting the challenges of the ISTEA to maximize system efficiency and address environmental issues in an open decision-making process rests upon people making the commitment to work together toward these dual objectives.

CONCLUSIONS

1. ***National Personal Transportation*** Survey, Summary of Travel Trends, FHWA-PL-92-027, U.S. Department of Transportation, Washington, D.C. (March, 1992).

2. ***IVHS and the Environment: New Models for Federal, State and Local Cooperation in the Application of Advanced Transportation Systems for Environmental Improvements in Urban Areas,*** State and Local Policy Program, Hubert H. Humphrey Institute of Public Affairs, University of Minnesota, (September, 1994).

3. ***Benefits of Traffic Control Signal Systems Are Not Being Fully Realized,*** U.S. General Accounting Office, Washington, D.C. (March, 1994).

TRANSCOM'S DEVELOPMENT IN NEW YORK, NEW JERSEY AND CONNECTICUT: MULTI-JURISDICTIONAL ISSUES IN ITMS

Matt Edelman, TRANSCOM

TRANSCOM is a coalition of traffic and transit agencies in the New York, New Jersey, Connecticut metropolitan region. TRANSCOM and ITMS share an essential guiding principal. As Tom Urbanik of Texas A&M and others have noted, ITMS is "multi-agency, multi-disciplinary, multi-modal and multi-jurisdictional," and it "should be transparent to the user . . . and responsive to local needs." The New York metropolitan area, with literally hundreds of government jurisdictions with enormous variation among their missions, is an excellent testing ground for this guiding principal.

This white paper will identify the multi-jurisdictional issues in developing, implementing and managing multi-modal ITMS. With illustrations from TRANSCOM's experience, it will demonstrate how working relationships can be developed among modes, among states, cities and counties, between toll authorities and DOT's and between police and civilians.

General Principles of Multi-Jurisdictional ITMS

Over the last several years, we have found that the lessons we have learned in developing a multi-jurisdictional ITMS coalition are more universal than we originally thought. Through discussions with colleagues from other regions, and through research done by organizations such as USDOT's Volpe Center and the ATA Foundation, we have found that the issues we have been dealing with are not necessarily unique to the large, jurisdictionally diverse New York metropolitan area. These general principles include the following:

- **A** lack of authority should not deter a coalition from pursuing its mission with confidence. No one has to be "in charge" for a regional coalition to function effectively. Often it is this very lack of centralized authority which creates an environment in which different jurisdictions are willing to cooperate.

- To be effective, coalitions should focus on things that truly are better done collectively. The coalition's leadership and constituency must be convinced that the specific activities being pursued are best done collectively. Otherwise, the coalition will wind up competing against some, if not all, of its own members.

- No matter how high minded the goals of a coalition, and no matter how much lip service its leadership may pay to these goals, no coalition can stay together it is just built on a sense of obligation. To develop from an abstract ideal into a going concern, a coalition has to help its constituent agencies do their business and serve their customers more effectively.

- There should be no inconsistency between the self interest of each agency and the collective, regional interest of the coalition. For this to be done, there has to be a clear differentiation of roles between the coalition and each constituent agency.

- While uniform procedures among the member agencies may be desirable in making a coalition effective, that is unlikely to be the situation in which a coalition that has no authority over its members fmds itself. Thus, it is up to the coalition to develop a flexible system to adapt to this situation.

- Even if the coalition itself may have a uniform set of goals and objectives, the motivations among the member agencies for participating or not participating in the coalition can be highly variable. The coalition must adapt to each one of these motivations, often having a separate strategy for individual agencies.

- Even if executive management of a constituent agency supports a regional coalition, that does not necessarily translate into support for regionalism at all levels aud all sectors of the agency. Since many levels of an organization are required to implement the coalition's work, it is important to realize that obtaining support from a given agency requires a constant outreach effort.

Working Collectively with No One "In Charge"

It is TRANSCOM's mission to bring about cooperation among dozens of agencies on incident notification, regional incident management, and construction coordination, as well as to serve as a multi-agency test-bed for implementing ITS technologies. We are frequently referred to as the United Nations of transportation. Like the UN, TRANSCOM has enormous responsibilities and very little authority to carry them out. This lack of authority does not deter us, for our coalition can be very effective when our member agencies see how their individual and collective interests can be enhanced through cooperation.

Located in Jersey City, NJ, TRANSCOM is administratively and legally a unit of its host agency, the Port Authority of New York and New Jersey, though it is governed, funded and staffed by all of its member agencies.' TRANSCOM's Operations Information Center (OIC) is open 24 hours a day, seven days a week. It shares incident, construction and special event information simultaneously and selectively among over one hundred highway, transit, police agencies, and media traffic services, by phone, fax and alpha numeric pager. It maintains a shared data base of its member agencies' construction projects. When necessary, it brings specific agencies together when conflicts, such as parallel closings between projects, are likely to result without cooperative intervention and mitigation.

With funding and guidance from the Federal Highway Administration, TRANSCOM implements and tests transportation management technologies. This technology development program focuses on initiatives which are most efficiently done collectively. This could include installing a variable message sign (VMS) on one side of a state Iine to benefit another state. It also includes more cutting edge efforts, such as designing a regional architecture to ensure communications among its member agencies' current and planned ITS systems. Another joint ITS operational test involves TRANSCOM testing the use of electronic toll collection equipment for incident detection. In this case TRANSCOM is undertaking this effort in behalf of its members and FHWA.

The Regionalism Appeal: Going Beyond Obligation

The New York metropolitan area is immense, fractious and jurisdictionally diverse. Throughout its history, there have been many attempts at regionalism, some based on idealism, some on pragmatism, and some based on both. The agencies TRANSCOM deals with have enormous operating responsibilities, and they work in an environment of budget pressures and often intense oversight by the public, the media and elected officials. A coalition like TRANSCOM can not be seen by busy officials from these agencies as "professional do-gooder regionalists." If these officials are only involved out of a sense of obligation, their interest will ultimately diminish. Such idealism is important for motivating many of us on the TRANSCOM staff, but it is hardly in itself sufficient for transforming a coalition dedicated to ITMS from an abstract ideal into a going concern. What has worked for TRANSCOM is that its member agencies see that multi-agency response is often a necessary means for serving their customers.

Local Interests and The Regional Interest: Clearly Defining the Roles While Still Being Flexible

Just how TRANSCOM serves as a necessary means for helping its member agencies, and dozens of affiliated local agencies, to serve the travelling public, is best illustrated through examining a major incident. One of the best examples of a severe incident from the past year is the complete closure of Interstate 287, the Cross Westchester Expressway, for almost 24 hours. Not only did this incident affect travellers in all three states in the metropolitan area, it affected travellers in other parts of the Northeast Corridor. I-287 is an integral part of one of the two main corridors for people

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'The member agencies are: ConnDOT, NJDOT, NYSDOT, NJ Transit, New York State Thruway Authority, New York State Police, NYCDOT, Palisades Interstate Park Commission, NJ Turnpike Authority, Metropolitan Transportation Authority, NJ Highway Authority, MTA Bridges and Tunnels, Port Authority of NY & NJ, Port Authority Trans Hudson Corporation (PATH).

and freight through the New York metropolitan area. 1-287 is not far from the Tappan Zee Bridge, a major Hudson River crossing. This incident was caused when a propane truck went out of control and hit a bridge abutment early one weekday morning. The resulting explosion took the life of the driver and caused structural damage to an overpass.

In the case of this incident, the three TRANSCOM member agencies responsible for the operations and maintenance of I-287 (the New York State Thruway Authority, the New York State Police and the New York State Department of Transportation) had their hands full dealing with the problem on site. They were focusing on public safety, structural integrity, and on moving traffic on and off the Interstate, in cooperation with local authorities. There were a number of regional issues that had to be dealt with and this is where TRANSCOM assumed a significant role.

Notifications-The first regional responsibility involved the need to make extensive notifications. The initial call, and subsequent updates, came into TRANSCOM from the Thruway Authority's communications center in Albany. Through its alpha numeric pager system, supplemented in some cases by phone calls and faxes, dozens of agencies that needed to know were informed of the incident. This included dozens of local and county agencies on both sides of the Hudson River. Major agencies feeding traffic into this corridor from New Jersey and Connecticut were informed, as were agencies operating facilities in parallel corridors which could expect higher than normal volumes as the AM peak approached. Also included in this initial notification by TRANSCOM were the media traffic services, not only those in metropolitan New York but, with a few hours to intercept traffic coming from outside the region, in Hartford, Providence, Boston and Pennsylvania. One call to TRANSCOM saved the Thruway Authority from making dozens of notifications. This is particularly important in light of how busy they were with the incident.

Traveller Information-The second regional responsibility involved rapidly implementing an integrated, multi-agency mobilization of VMS and highway advisory radio (HAR). Every member agency with fixed and portable VMS and HAR makes these resources available to other agencies through TRANSCOM. As an example, ConnDOT mobilized VMS on I-95 south, warning their customers of the I-287 incident far enough in advance to utilize other major routes through the metropolitan area. They also mobilized signs in locations, such as Hartford, that intercepted some traffic in time to keep them completely out of the metropolitan area, taking more northerly diversion routes. Closer to the incident, TRANSCOM remotely mobilized the Thruway Authority's HAR.

This use of numerous HAR/VMS in three states that day reveals two key points for making multi-jurisdictional ITMS work. First, the self interest of each member agency was served by assisting with traveller information resources. The incident may not have been on their roadway, but it was their customers (customers who care about their total trip, not about specific agency jurisdictions) who benefitted. Second, different agencies have different rules about mobilizing VMS/HAR at TRANSCOM's request. Some want us to have direct access, some will do it themselves from a phone request from TRANSCOM, and with some there are even other variations of protocol. What's key for TRANSCOM is that we do not ask for uniformity of procedures from among these agencies. This lack of uniformity is our problem if we want to make the coalition work. A key lesson here is that if you don't have authority, don't pretend you do or try to get it, just meet your constituent agencies far more than half way and get the job done for them.

"Real Time" Construction Coordination-The third major regional responsibility for TRANSCOM involved minimizing construction that day on roadways that would be likely to be experiencing an increase in volume due to diversion around I-287. I noted above that TRANSCOM maintains a data base of its member agencies' construction projects and brings agencies together to work out modifications in scheduling when inter-agency conflicts exist.

Sometimes, though, we do not have the luxury of planning ahead and the closure of I-287 is a good example of this. While it maintains a long term data base of construction projects, TRANSCOM also keeps track of each day's activities throughout the region. Thus, as the day approached, we knew what was likely to be taking place after the morning rush. The records also said who was the engineer in charge on site. Numerous agencies agreed to either cancel construction for the day, reduce the amount of lanes taken or pull the construction if congestion resulted during the day. As an example, since the parallel George Washington Bridge/I-95 corridor was likely to be hit with diversions from the Tappan Zee/I-287 corridor, TRANSCOM asked the Port Authority to pull construction from the George Washington Bridge that day. The Port Authority willingly agreed to do so.

This third regional responsibility worked because, again, agency self-interest and regional, multi-jurisdictional interest **were** not in conflict. The Port Authority, for example, knew that its customers would be better served if construction were pulled that day. Further, they also knew, as had already happened on numerous occasions, that they could count on the Thruway Authority to pull construction for the Port Authority when there was a problem on the George Washington Bridge.

Seperate Strategies for Different Agencies: Incorporating Cities and Counties into Multi-Jurisdictional ITMS

The extensive example discussed above related to how and why the over one dozen large agencies in the TRANSCOM coalition have cooperated with each other. Another dimension to making our coalition work is how we incorporate dozens of other agencies, specifically cities and counties. While just bringing the member agencies together from three states sounds daunting enough, TRANSCOM also reaches out to municipalities and counties in order to ensure communication with all affected parties during major regional incidents. (All of TRANSCOM's member agencies are either state based or bi-state based, with one exception. The exception is the New York City Department of Transportation. Given the magnitude of New York City and its critical importance to our region, NYCDOT is a major player in the transportation system and is an essential member of TRANSCOM.)

Just why TRANSCOM needs to communicate with municipalities and counties is illustrated by the some of the Primary highways in New Jersey. While the six miles of Route 1-9 between Jersey City and Newark are owned and maintained by the New Jersey Department of Transportation, incident response is done by the police forces along the route, Jersey City, Kearny and Newark. Similarly, NJDOT owns and maintains Route 17 in Bergen County, but the Bergen County Police handles incident response. Each of these four agencies is tied into TRANSCOM's operations information center and each is on our alpha numeric pager system. Similar examples exist throughout the region.

The variability among the counties and cities in our region, including those on our network, is extraordinary. They range from a prosperous suburban county with many Fortune 500 headquarters and an economy bigger than some states to small, blue collar municipalities of under ten thousand close to the urban core. Behind each of the dozens of relationships that TRANSCOM has developed is a seperate and unique story; among these communities, there is by no means a single set of motivations for cooperating with a regional coalition. As was discussed earlier with regard to procedures for mobilizing our member agencies VMS/HAR, there is no uniformity. With regard to motivating counties and cities, this lack of single set of motivations is, again, our problem. We the coalition must constantly adapt and meet our constituents far more than half way.

A few examples of this issue are quite simple and unglamorous. For example, a number of years ago, many local police departments in New York State could not call incidents into TRANSCOM because they were not equipped to handle long distance calls to New Jersey. The solution was the institution of an 800 number and the result has been a significant increase in participation.

Another example related to costs for placing TRANSCOM's alpha numeric pagers at a number of police communications desks. While the cost of such rentals is well under $500.00 per year, a number of police agencies that otherwise wanted to cooperate did not want to pay the expense. In general, the reason for their resistance was not so much the cost, as the bureaucratic procedures required to get the budget item approved. The member agencies realized that since these police departments were reporting information on their facilities, it was important to get them on the pager system. Rather than create a complicated accounting and billing system for relatively small expenses, the TRANSCOM member agencies decided to make the pagers available for free, including the cost as part of TRANSCOM base operations expenses.

Dealing with Variable Support within a Large Agency: The State DOT Example

The experiences of one of TRANSCOM's steering committee members (from one of the four DOT member agencies) illustrates how support for a coalition can vary significantly within an agency. At the beginning of this article, we noted TRANSCOM's role in providing for traveller information systems on one agency's property for the benefit of a neighboring jurisdiction. This person was the representative of the agency on whose property the device, in this case a VMS, would be installed. When he was arranging for permits for installation of the VMS, he learned that a strong belief in regionalism does not necessarily work its way down to all members of the field engineering staff. In the proposed access permit, the field engineering staff put in a series of restrictions on use and control by the neighboring agency that severely diminished the real time usefulness of this equipment for the neighboring agency.

Since that time, the agencies involved with this VMS have made considerable progress toward an amicable understanding on its installation and operation. Our steering committee colleague, though, had an interesting observation on multi-jurisdictional ITMS. "You know," he noted, "I have spent the last few years advocating new, multi-agency ways of solving problems. It is something else, though, to actually have to test one's commitment to coalition building when it affects my own agency's control over its own facilities. While we will ultimately work this out, it shows that these commitments are not always easy to make."

This recent experience reveals another key point about making multi-agency ITMS work. Namely, there is a major intra-jurisdictional element that needs attention if the multi-jurisdictional element is going to work. Surely, it is important to have an advocate in each agency such as the colleague in this anecdote, one who has access to top management, as well as to people in the field. Nonetheless, it is a tall order to have everyone you need in a huge bureaucracy be knowledgeable about what you do and on your side at any time. In effect, you never reach an optimal point in coalition building, it is a process involving constant outreach and constant renewal.

Separate Strategies for Different Agencies: The Transit Dimension

Inter-agency cooperation on transit incidents has become an extremely important activity at TRANSCOM. In order to understand why these alliances with the transit agencies have developed, it is useful to view the bus and rail sides of transit separately, since their motivations for working with our multi-jurisdictional coalition are not entirely the same, Bus operators are extraordinarily dependent on our highway member agencies in order to deliver a service to their customers; put another way, they are by definition involved in a multi-agency alliance. Commuter rail and rail transit operators have their own discrete right of way (and we have no street running light rail in our region). Rail transit incidents tend to have to have a higher threshold of severity before they have an inter-agency impact.

New Jersey Transit Bus Operations was an early participant in TRANSCOM and they continue to be active. They operate all over New Jersey, and serve midtown, uptown and downtown New York through three separate Hudson River crossings. On a typical run, their buses can cross over roads and crossings under the jurisdiction of NJDOT, NYCDOT, the Garden State Parkway, the New Jersey Turnpike, the Port Authority and a range of county and municipal traffic departments. Their commitment to sharing information with our regional coalition is logical one, in which agency interest and multi-jurisdictional interest are compatible. TRANSCOM's focus is on incident and construction information as it affects entire corridors and the region: NJ Transit buses travel on corridors and not just one agency's facility's. With NJ Transit, TRANSCOM has gone beyond fax, pager and phone to have a direct two way radio linkage with NJ Transit's communications center. Further, with their buses equipped with radios, NJ Transit buses have served as "probes" for TRANSCOM, calling in incident information.

In encouraging rail transit operators to share incident information with TRANSCOM, we have worked with a different set of assumptions. As noted above, because rail operators usually have unified control of entire corridors, the inter-agency impact of an incident tends to be less. TRANSCOM's relationship with PATH, the Port Authority's transit system between New Jersey and Manhattan, illustrates this point. PATH was also an early participant in TRANSCOM and they too continue to be active.

Particularly for work trips, PATH exchanges passengers with other major transit operators in the region. On the New Jersey side it connects with, among others, NJ Transit commuter rail and bus lines in Newark and Hoboken and, on the New York side, with NYC Transit Authority subways and buses. A major delay to a PATH line to or from Newark or Hoboken has a significant regional impact. It can affect thousands of NJ Transit and Amtrak passengers expecting to change to PATH at Newark to gain access to lower Manhattan. Similarly, when PATH's line from the World Trade Center in lower Manhattan to Newark goes down for the afternoon peak, there is a major diversion to the New York City subways to get passengers to Penn Station in midtown, as well as the Port Authority Bus Terminal. When this happens, TRANSCOM quickly notifies the NYC Transit Authority, given the impact on crowd control, pedestrian movement and token sales at the World Trade Center.

The inter-agency linkages for a major PATH incident are far more numerous than the two examples cited above. The key issue for PATH is that it is in its operational interest to share information with TRANSCOM. The burden upon its operations and communications staff during an incident is enormous; one call to TRANSCOM removes a significant multi-agency communications burden from them. Through TRANSCOM, PATH is also a significant consumer of incident information from other agencies. Further, building on the logic used by our highway members in multi-agency sharing of VMS and HAR, it is making its Metrovision television monitors available to provide information on incidents on connecting agencies' facilities.

Understanding Police Motivations Toward Coalitions

In 1992 I co-authored a paper for a TRB ITMS conference with a member of the law enforcement community, Sergeant Paul Eiieinhofer of the Bergen County, NJ Police. Thus, the relationship between police and multi-jurisdictional ITMS was a key focus of that effort. At the time, we noted that:

> . . Police are often more resistant to ITMS initially than engineers, the latter being more responsive to the technical arguments for ITMS. Engineers are more inclined to see regional linkages because of their training. Police, on the other hand, must live from day to day with the actual on site effects of an incident. They know first hand just how bad it can be out there. So when they are ultimately convinced that ITMS will help them in their work, they can become extremely enthusiastic proponents of regional approaches.

What Sergeant Eiieinhofer and I said in 1992 holds true today. Since that time, one of our most successful efforts was in planning for and cooperating during a major special event that affected travel in the entire northeast. Our partner and biggest advocate throughout this effort was a police official. Similarly, the individual who has shown the greatest reticence about participating in our coalition in the last few years is also a police official. In our experience, police bring an intensity and dedication to their work that can be a major asset in building ITMS, as long as they believe in what you are trying to do.

Issues Unique to Toll Authorities

Toll authorities are a major player in ITMS in our region and, given national trends, they are likely to be an even greater factor in the future elsewhere, as well. People have at times asked whether our toll authority members are willing to participate in regional, multi-jurisdictional coalitions. This question is asked from the perspective of whether toll authorities are willing to accept the potential revenue impact of diversion from their facilities during major incidents.

When toll authorities know they can not handle the volume during an incident at an acceptable level of service, they willingly accept TRANSCOM and its member agencies' help in keeping traffic away from the impacted facility. However, when information on an incident on a toll road comes from a third party, we always seek permission of the toll authority first prior to making a notification. Particularly when toll authorities have major construction planned, they encourage diversion from their facilities and are appreciative when agencies running parallel facilities pull their own maintenance and construction work to accommodate the alternate demand.

As one toll authority official has said, "we have reached a point where demand far exceeds capacity; service to our customers includes letting them know about those occasions when our capacity is severely restricted due to major incidents and construction." Participants in our coalition from the toll authorities also know that the revenue impact ultimately equalizes over the course of a year, as they in turn accommodate surges in demand due to diversion on other facilities.

In conclusion, this paper has examined how TRANSCOM has been able to bring a range of agencies into a multi-jurisdictional ITMS. I have looked at the issues from a number of dimensions: cities and counties, state DOT's, transit agencies, police agencies and toll authorities. In each case, we have tried to go beyond the "do-gooder" reasons for building a coalition to actually understand how to motivate an agency to make a clear and willing connection between the regional interest and its own interests. While we assumed a number of years ago that the issues we are dealing with are unique to our own large and jurisdictionally diverse region, we have actually found that the lessons we have learned are more universal than we originally thought.

SYSTEM ENGINEERING: A SHORT COURSE IN THE OBVIOUS

Tip Franklin, TRW, Inc.

ABSTRACT

System Engineering is truly one of the staple buzz words of the ITS movement and becomes even more useful when trying to address and accommodate the various elements of an Integrated Transportation Management System (ITMS). Yet if you were to ask a number of experts (from out-of-town and carrying a briefcase) to define the term you would receive a virtual panoply of answers. So the thrust of this paper is to discuss the basic system engineering methodology with the hope that a clear understanding of the process will lead to a tighter definition of the term. More importantly, I would hope that this clearer understanding will lead to a more widespread utilization of the complete process for while there are a number of "System Engineers" running around the market place, there are very few "Systems Engineers"!!

The complexities of meeting all of the needs, wants, and desires inherent in a mature and robust Integrated Transportation Management System (ITMS) requires a central operating system capable of efficient integration of multiple component systems. Given the potential for fragmentation of focus and dysfunctional design stemming from the "multiples" (agencies, jurisdictions, modes and disciplines) resident in and supported by an ITMS, without a structured approach for development of this core operating system chaos would reign supreme. This structured approach is known as System Engineering.

The term "System Engineering" or "SE" originated in the defense contracting world. These contractors have been exposed to the process in detail since most Government procurements are very stylized and configured to facilitate this process (in fact it is MIL-STD-499B) which reads as follows:

> "System Engineering is the application of scientific and engineering efforts to (1) transform an operational need into a description of system performance parameters and a system configuration through the use of an interactive process of definition, synthesis, analysis, design, test, and evaluation; (2) integrate related technical parameters and ensure compatibility of all physical, functional, and program interfaces in a manner that optimizes the total system definition and design; (3) integrate reliability, maintainability, safety, survivability, human and other such factors into the total engineering effort to meet cost, schedule, and technical performance objectives."

In a basic sense "System Engineering" is the name given to the structured process followed to move an idea from concept to reality. It can be applied equally well to product and process development, to changes, modifications and improvements or to verification processes. Since I believe that one of the major needs of a successful ITMS implementation is for some form of a decision support or management system to serve as the core integrating element, I would suggest that you let the development of one of these systems be the mental backdrop as I lead you through a discussion of the model. Further, since this paper is being addressed as part of an introductory session I will keep it very generic and stylized to aid in building a common reference point for discussions throughout the remainder of the conference.

Basically, system engineering is the process that 1) brings together all of the requisite diverse expertise in a timely manner to accomplish the primary life cycle functions necessary to define, design and verify system elements of products/processes; and 2) effectively directs and controls the totally integrated engineering effort. The core or cornerstone document for this controlled, efficient and integrated growth is a comprehensive front-end study based on a thorough analysis of the real or to-be-implemented management philosophy and those uncontrollable variables such as fiscal constraints, political considerations, environmental impacts, "upstream" requirements, etc. that will impact development of the system. This is where real world considerations shape the development the most. Not to say that changing external conditions won't have an impact later, it's just that they have the biggest push at this stage.

Generally, design of any system's life cycle must address all aspects of planning, acquisition, training, operation and, eventually, tear-down. The length of this life cycle can vary from days to years but still there is a constant requirement to establish the basic operating parameters as early as possible and to identify the interrelationships of the various parts of the total system. Within this overall system description, each functional/specialty area should be described in as much detail as possible using the same life cycle phases. Its relationship to other sub-systems and to the central controlling node should then be documented. With this baseline system description in hand, it will be far easier to add, modify, or shrink capability to meet future emerging requirements thus facilitating a controlled growth of the basic overall system. The resultant performance and system specifications establish the baseline upon which to build. Additionally these parameters will provide the basis for trade-off analyses for future acquisition decisions. How do we get there? Essentially the operating system is described, then a backward planning sequence is applied to delineate the milestones applicable to each individual subsystem as well as those applicable to the system as a whole. This is not to imply "once done, always done" for as new requirements merge (the Automated Highway System) this system description can be amended to accept and/or accommodate growth and do so in a controlled manner. In essence, the system description provides the guidelines for any future incremental growth. It must be a living document with a preplanned method of accommodating and managing change. A well-planned SE process will facilitate the latest development buzzword-Concurrent Engineering. With that as background let me address the Waterfall Chart (Fig.l), the traditional method of depicting the system engineering process. There are fancier models for development, i.e., the Spiral Model, but this is a tried and true package.

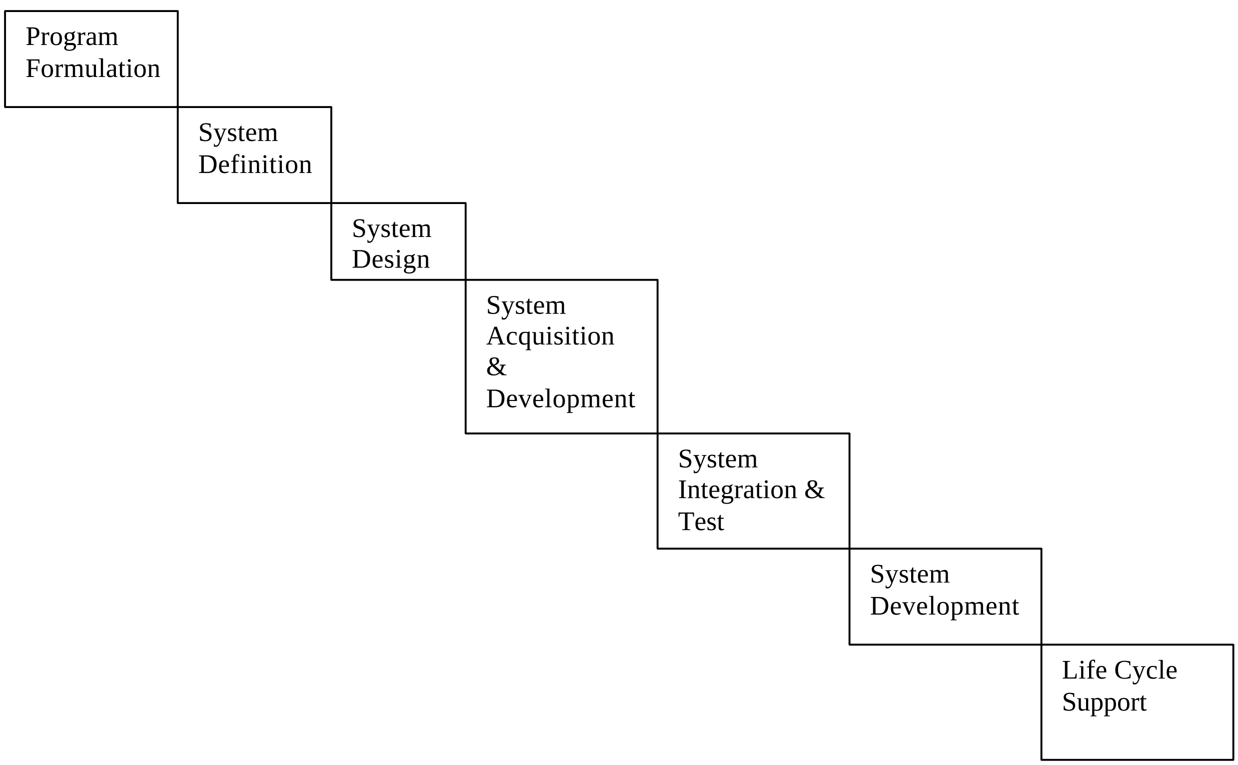

Figure 1. The Waterfall

In the beginning-**Program Formulation** Here we accomplish the decomposition of the task requirements. Given that a management system exists solely for the conduct of functions supporting a defined requirement and the associated asks, it is critical to get right down to answering the question-WHAT' s THE JOB? There is a critical need to scope the task requirements-now and future. These will put bounds on the development task and provide the parameters to do prioritization as driven by funding, schedule or one of the uncontrollable variables mentioned earlier. Having developed the program requirements, we can generate the cost and schedule estimates and the programs, plans and procedures strategy. Notice that I have used thewords "estimates" and "strategy."

Next there is **System Definition.** In this stage we do some serious tradeoff and analysis work. We should expect to have identified the institutional requirements (what will be the impacts of the Personnel Merit Board?) and generated a validated schedule (do I have to match the Fiscal Year spending profile to align with Federal dollars?). We also should expect to identify the technical baselines, staffing (technology doesn't necessarily bring smaller staffs) and operating concepts (centralized vs. decentralized), security requirements, demographics, budget projections and, of no small importance, the impact of and on other projects. The products expected from this phase will be a preliminary bid package, conceptual design, life cycle cost and schedule, system and interface specifications and the system test and acceptance plan (you should know now what will make you happy in the future). Pretty ambitious step!! But if you believe in the old parable that a journey of a thousand miles begins with a single step, you will go a long way to achieving final success in a timely and efficient manner if you take the time to do this well!!

It is ***this*** area where I have found the greatest variation in levels of completeness as I have talked with various transportation agencies. Let me just offer that being as precise and complete as you can here may more than repay the cost to get there. I say this because the more imprecise the front-end documentation, the less documented the requirement, the higher the risk as seen by any potential system designers. And "Risk" translates to higher bid prices on proposals. In short, if you know what the job entails, can translate it in terms of requirements documents, can put it all together in a conceptual design and have well-defined acceptance criteria, you are on your way to having a very productive and efficient development process.

We are on a roll now as we get to the **System Design Phase**. We've gotten through the "What's my job and what do I need to do it?" Now we are going to go buy it. But wait! There is a proper way to do that as well. Although it is fun to go ripping through the technologically superior whiz-bang things (non-intrusive VIDS, spread spectrum, mega-power computing, etc.) in the market place and buy one of each. We need to do a bit more on the thinking side before emotion runs rampant. There really are several sub-steps in the process, the first of these being Critical Item Evaluation. Here we resolve the risk issues, look at site considerations and take a good hard look at what is on the horizon technically.

Having done that we can then (and only then) move into Preliminary Design. We ensure that all valid requirements as established in the first step, have been included in the design, that we have approved the long lead items for procurement and that our Staffing and Operating Plans are prepared. The product of this stage is a set of Preliminary Drawings.

This leads to the Final Design where once again we validate that we have not dropped nor exceeded our ability to meet the requirements and we establish a training program. The products of the stage are Construction Drawings and Procurement Packages.

Here's where we hit the light of day-the **System Acquisition and Development Phase.** If there is a major disconnect with the proper application of the System Engineering process and the real world, it is that construction/development of many of the management systems I've seen have entered the process at this point. A problem or a need exists, somebody has a great piece of technology, money is available, so construction or acquisition begins. Does the word "Topsy" strike a familiar chord? No one takes the time to go through the front-end, almost rote, process steps to validate the decision. With the gleam of high-tech in their eye, they buy something NOW!!!!! Yet if we were to do it right, then this step, which could be called Construction or Acquisition, would not only verify that it was built as designed but that the product was built as designed from a system perspective. It is tough to determine that the requirements were met if we haven't established the requirements. However you get to the point, right or wrong, you would obviously expect to get something from this process-the "As Builts."

Remarkably you would expect that since we have now entered the process that all else would conform to the model. Again, not so fast. **System Integration and Test** has a great ring to it. Yet it is one of the most over-used, misunderstood terms I know. Just as the Requirements Definition phase sets the standard, SI&T ensures the performance. Actually there are really two steps in this stage-Installation and Integration and Test and Operation.

In the Installation and Integration step we implement a Test and Acceptance Program (the sell-off) and conduct a training program. You should expect to see installation drawings laying out a set of functional and interactive subsystems all of which lead to the fully functional system.

But to prove it works you have to submit the system to some serious down home testing. This is the purpose of the Test and Operation step in the process. Based on an identification of the key subsystems you submit the whole package to a process whereby you sign off each key and critical element by either test, analysis, demonstration or inspection. This is all done in accordance with formal Test Plans and Test Procedures. This is the stage where the independent Quality Assurance process earns its keep. When you are done you have tested the system in almost the reverse direction from the way you built it: In short, you design from the top down and test from the bottom up: you test each piece, you test each piece as a part of a subsystem, you test each subsystem as a part of the whole and you test the whole as an entity to ensure that it meets the requirements you established in the Program Formulation stage. My other plea here is to be sure that the pressure of time does not override the requirement to do a good SI&T.

And then suddenly you are about to hit that magic stage called Deployment. It will be there, it will work and all of your cares will be gone.

You aren't done yet. There's a thing call Life Cycle Support (some would cheapen the phrase by referring to it as "Maintenance"). To be a complete design and a truly integrated system we need to know going in what our life cycle costs and procedures must be. We need to do an analysis of the "Pairs and Spares" and do an interchangeability analysis. Many vendors use similar components but under different part and serial numbers. It would be nice to know that the Flonoteny Rod Mfg. 's part # 2717 used to cleviate kelterpflime is the same as AJAX Supply's part # a-649 that is integral to the operation of the light and sound machine. You need to catalogue and analyze those bits, parts, and pieces that make up your system. You'll need to address not only initial capability training, but sustainment and growth training for your work force. You'll need the "As-built" drawings and Operator Manuals and to establish a set of Logs for each piece of the system requiring a detailed history of operation and maintenance activities.

And yes there is something missing here. Configuration Management (CM). The four basic elements of CM are Configuration Identification, Configuration Change Control, Configuration Status Accounting and configuration Identification. A Configuration Management Plan (CMP) defmes the direction and surveillance applied to ensure positive identification, control and status accounting of hardware and software performance requirements and the attendant testing through all of the Life Cycle phases. Effective CM requires efficient integration of many organizational responsibilities but the inherent differences between hardware and software as well as the unique standards and methodologies applicable to the two disciplines require separate approaches be applied. A good CM plan describes the procedures for proposing changes to the configuration baseline, their evaluation and approval and the methodology for implementation following approval.

As a minimum, the Hardware Configuration Master Plan (HCMP) describes the baseline equipment configuration and establishes program control and accounting procedures including: a family tree block diagram of the overall equipment showing all assemblies and major purchase parts, item quantities and parts numbers (as available). The Software Configuration Master Plan (SCMP) provides the required management visibility into the software analysis, design, development, test and operation environment.

Where do you go from here? Given that the half-life of computers is shrinking and that requirements are ever emerging, you have some serious pondering to do. But wait-you have established the process to do so. You have a clear focus on today's requirements and the resulting operational concept; you have implemented an efficient and focused operational design and you have a configuration management process to allow incremental and efficient future upgrades.

I'd love to tell you that it would be a total bed of roses and a piece of cake to design a system but it just isn't so. But using an ordered process makes it far easier and efficient with far less wasted motion and resources. Please understand that the Waterfall Chart isn't the only way to accomplish System Engineering. It is a very simplistic, and possibly misleading, device since it tends to represent a sequential process which is not the case at all. In fact, many of the steps are overlaid and repetitive but this occurs as a function of each situation so it is impossible to show all potential combinations and permutations.

In closing, I would hope that you've gained several teaching points from the foregoing. To work the SE process well:

1. You need to firmly establish and document requirement(s). What's the job and what do I need to do it?

2. You need an orderly process to ensure that each requirement is addressed and done so considering the impact of the external variables.

3. You need to resist the technology temptation.

4. You must insist on and provide schedule time for SI&T.

5. You must establish a configuration management scheme and adhere to it without exception.

From the foregoing have intended to lay out a process whereby you can take the overall concept for implementation of an ITMS and turn that into a developmental process for the core system that will serve as the glue. And this is not to say that the process only applies to the core system. It can (and should) be applied to every component system as well-it is only a matter of perspective. What is an external condition for a component system may well be a feature of the core system. It will address development of inter- and intra-system voice, video and data communication, training needs, operational procedures, training needs and budgeting.

It may be difficult to identify that point at which you transition from thinking about operating a system to designing a system. And that's just fme. You don't necessarily want to let technology run rampant. It can support change; it shouldn't necessarily drive it. Other than that all I would tell you is to have a good time using the process. The next time somebody drags a high-tech widget in the door you can nod knowledgeably and consider his offering from a systems context. You can look him in the eye and ask "what's this going to do for me today?"

Good Luck!

AN ITMS ARCHITECTURE CONSIDERED

Jim Kerr, Greg Mosley, NET Corporation

SUMMARY

The content of the paper is intended to provide an overview of the driving factors which directly impact the development of an architecture for an Integrated Transportation Management System (ITMS). In many ways, the paper places emphasis on the need for the Transportation Professional and the Systems Engineering Professional to find common ground, such that the requirements of the Transportation Management function drive the development of a Systems Engineered architecture, and in turn the physical systems themselves. In summary the paper, considers the following major themes:

- Systems Engineers are advised to consider the scope of the ITMS challenge from the perspective of the benefits which the Transportation community envisage when referring to ITMS Transportation professionals are urged to consider the means by which they express their requirements to Systems Engineers. Figure 4 contains a very high level system architecture. At first blush, the transportation professional may consider the drawing too detailed to be easily understood. However, the Systems Engineers will undoubtedly require additional detail before embarking on design development. What is required is the ability of the design team to successfully bridge the level of understanding between the Transportation Engineers/Planners and the Systems Engineers. The formation of a Requirements Planning Team made up of representatives from both disciplines is recommended.

- The ITMS concept, in a nutshell, endeavors to integrate all modes and all roads into a “system of systems.” The position, however, is taken that much variation is present, region to region, in the manner in which comparable agencies operate their specific transportation services. It is suggested that the nature of these variations have a profound impact on the development of an ITMS architecture. As a result, the concept of coupling National System Interfacing Standards (to assure seamless inter-regional travel experienced with such entities as CVO operations) with specific regional ITMS architectures is suggested.

- A conceptual ITMS architectural model is presented which essentially applies an onion like structure in the layering of critical system elements. The essence of the model draws on established and emerging open systems standards to provide the cohesive agent in the physical implementation of the architecture.

- The conclusion of the paper notes that it is essential for agencies which are co-operatively deploying an ITMS, to develop a regional configuration management plan (CMP) and establish a mechanism to ensure the CMP’s integrity remains intact throughout the entire life cycle of the ITMS.

PAPER ORGANIZATION

The paper is organized into four sections as follows:

1. The ITMS Challenge:
   Intended primarily for systems engineering staff, this section provides an overview of the types of benefits anticipated within the transportation community in elevating current transportation systems to au integrated operation. The section concludes with a conceptual overview of the functionality envisaged in an ITMS.

2. The Architecture Development Process:
   Intended primarily for Transportation Engineers/Planners, this section provides relatively brief description of the recommended steps necessary to establish a comprehensive and robust system architecture, using structured systems engineering principles.

3. Important Conceptual Components for an ITMS Architecture-or-Where to get started:
   Intended for both transportation engineers/planners and systems engineers, this section identifies a number of items which are strongly recommended for consideration in the early stages of development of an ITMS architecture.

4. Conclusions
   A number of conclusions are drawn concerning the process and key considerations suggested for the ITMS architecture development process. The concept of establishing and maintaining a formal regional configuration plan (CMP) is introduced.

The paper is intended strictly as a summary overview of the significant factors which are present in the development of a systems architecture. Of these factors, perhaps none is more significant than the ability of the design team to bridge the information gap which typically exists between transportation and systems professionals.

THE CHALLENGE

Integrated Transportation Management Systems (ITMS) seemingly represent the next evolutionary step in the deployment of advanced technologies to meet surface transportation needs. ITMS, as a turn of phrase, itself conjures a vision of an integrated environment of operational, institutional and technological instruments into a common mechanism for covering the full gambit of multi-modal trips planned for our transportation network(s). While, perhaps, there is an overall vision of ITMS which is shared amongst Transportation Engineers and Planners (with allowance for variances in individual opinions), there is still much ground to be covered between this vision and the rather exact science applied by our technologists in the delivery of systems to support day to day operations. Therefore, prior to the development of an ITMS architecture there is a requirement to add definition to the scope of the ITMS challenge. For the benefit of the Systems engineers, Appendix A provides a summary of the scope of this challenge through the examination of the potential benefits associated with ITMS. The following provides a summary of the referenced content:

- The traditional application of advanced technologies to surface transportation needs focused on the ability of agencies, acting largely in stand-alone operations, to address both recurring (e.g., rush hour traffic) and non-recurring (e.g., incidents) congestion, through surveillance and typically local control techniques. Benefits of these systems included a generally more efficient movement of persons and goods characterized by increased safety levels aud reductions in vehicle hours of delay

- ITMS provides the opportunity to gain both incremental and new benefits over the traditional systems through the integration of all transportation agencies' (all modes, all roads) management and information systems. These benefits are associated with an area wide or corridor level response to the full range of mobility needs within a region.

- Variances, region to region, in basic operational philosophies and policies have a profound impact on the ultimate ITMS deployed

- Deployment of an ITMS provides an opportunity to bridge multi-modal planning and design work with day to day inter-modal operations

Figure 1 provides a conceptual overview of the potential integration of transportation services in a manner which would return the benefits described in Appendix A. Essentially the intent is to establish a critical mass of data and control access which enables area wide transportation management/demand strategies to be deployed both in real time, and as strategic interventions to longer term travel demand patterns. In a nutshell, the intent is to establish a "system of systems" which integrates all modes and all roads.

While figure 1 represents this mass of data as single entity, it is not intended that such an implementation necessarily focus on the establishment of a central depository of fused data. Rather distribution of the system components (data, control sequences) across an open system environment, where data and control integrity reside with the operating agency, may well represent a more effective manner to gain local consensus and hence the deployment of such a system.

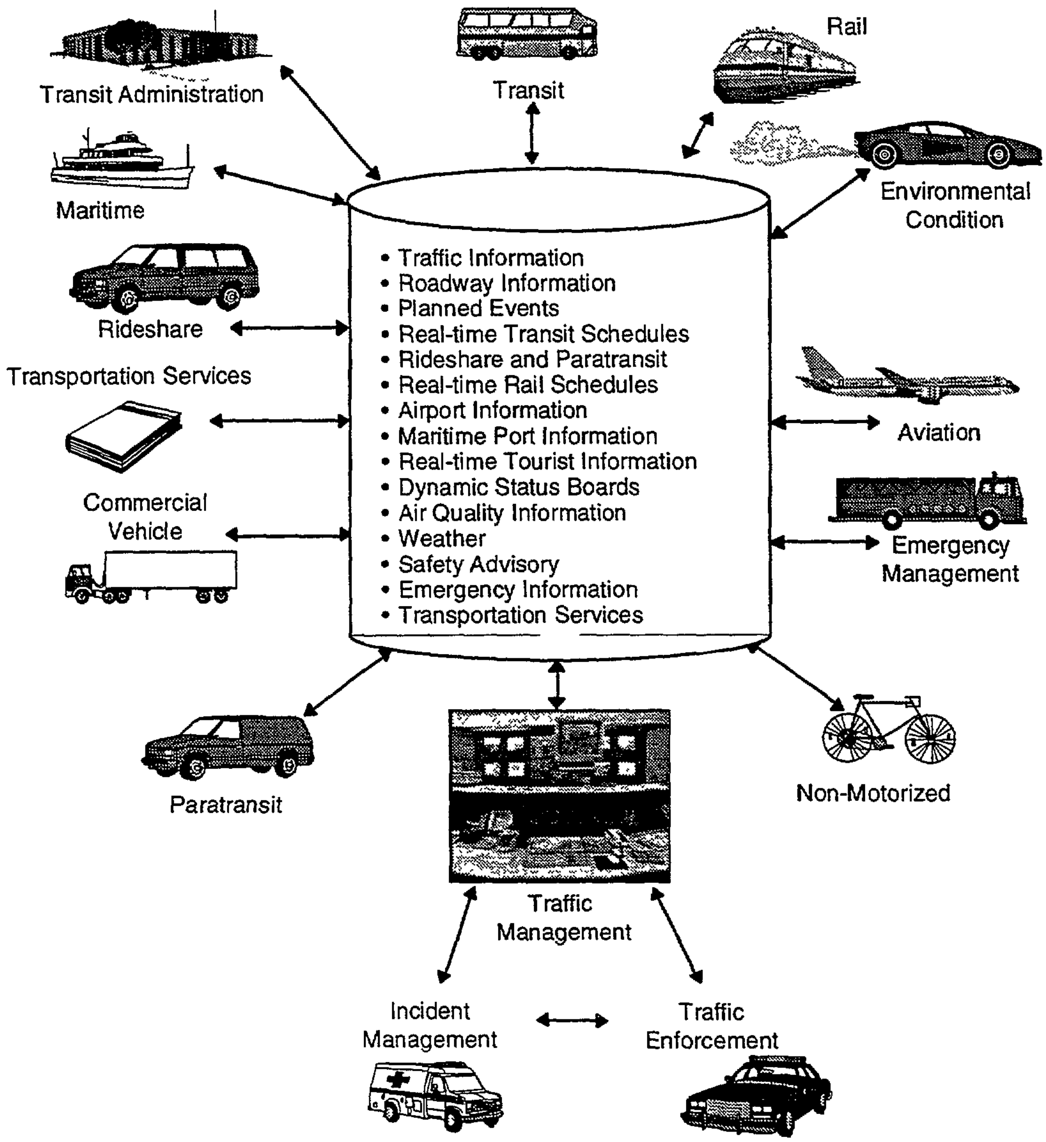

Figure 1. Conceptual ITMS

THE ARCHITECTURE DEVELOPMENT PROCESS

Overview

In consideration of the broad technical scope of an ITMS architecture, the balance of this paper focuses on the development of an architecture for the systems found within the many operations centers (transit, ports, traffic, private operations, etc) which comprise an ITMS. An equal or greater length discussion can be made for the supporting ITMS field infrastructure and wide area communications network. However, the first point of interface for ITMS will likely occur in the management centers. As "smart" field devices are deployed, however, expect to see a broader scope for the system integration exercise.

Prior to engaging in a discussion on the steps required in the development of an ITMS architecture, reference is again drawn to figure 1. Depicted in this figure is a conceptual integration of the various elements of any transportation network. To gain an early focus for local agencies, it is often useful to quickly establish a conceptual system architectural model which provides a framework to flush out the technical details necessary to complete the systems engineering process. Also, specific attention needs to be paid to the existing or legacy systems (as opposed to new systems) which are currently in operation. Hence an effort to establish a migration path from the existing case to the ITMS is critical. One approach to deal with this scenario is to introduce an open systems component (hardware and software) which taps the "shared memory" (assuming no licensing violations are incurred) portion of the existing systems, thus gaining access to both data and control parameters.

A measure of success has been gained in the representation of the ITMS implementation as an onion model, where the ITMS applications are layered into the architecture using industry recognized open systems standards. Figure 2 portrays this conceptual model. Each of the concentric circles in the model represent an industry recognized and supported open systems standard. A summary of the critical system interfaces (and hence the need for open system standards) follows:

- The core of the onion is made up not a single piece of hardware but rather, the various pieces of hardware (and their operating systems) found amongst all of the agencies involved in the ITMS. To be sure, not all agencies will agree on a common piece of hardware to be used by all, and in certainty attempts to establish hardware to hardware links (where all hardware is not common) will lead to trouble. Therefore, there is a need to elevate the integration effort to a higher systems management level. Recognize, however, open system standards for operating systems do exist and should be fixed in the early stages of development.

- The next layer in the onion represents a significant element in the successful integration of the ITMS: data management and Inter-process Communication (IPC). Data Management provides the mechanism to share data between systems and users in a seamless fashion. The inter-process communications process essentially enables real-time interfaces, using an open "publish/subscribe" paradigm. This layer of the model is ideally where all communications between new and existing systems takes place. The need for open systems standards, not proprietary "library" routines, at this level are critical.

- Layered on top of the data management and IPC layer are the ITMS applications. The applications include (but are not limited to) signal systems, freeway systems, bus operations, rail operations, emergency services including law enforcement, port operations, CVO needs, etc. The intent is to avoid directly binding applications together by communicating between applications through the data management and IPC layer. Tightly binding application to application is strongly discouraged since even a minor change in hardware, or in the data dictionary can drop the integrated systems out of alignment. Further, the ability to add and delete applications from the ITMS is simplified when the use of open standards effectively allow a "plug and play" environment

- The outer layer of the model is the User Interface. Most common today is the use of graphical user interfaces (GUI). Open standards exist for user interfaces which give all operations a common look and feel. This allows remote operation of all applications within the ITMS.

The Development Process

An ITMS architecture is made up of two essential and separate parts, the technical architecture and the information architecture. The components of the technical architecture come from the computer industry vendors; these include workstations, servers, routers, bridges, local-area networks, wide-area networks, peripherals, databases, operating systems, etc. Figure 3 depicts a generalized distributed technical architecture for the Yosemite Area Traveller Information (YATI) system. The components of the information architecture are designed from inside the enterprise by a process called Information Engineering. Information engineering identifies the entities (objects) in an enterprise about which information is stored. It decomposes the functions of the enterprise into processes and builds data models and process models for each functional area. These models are stored in a repository referred to as an encyclopedia or dictionary.

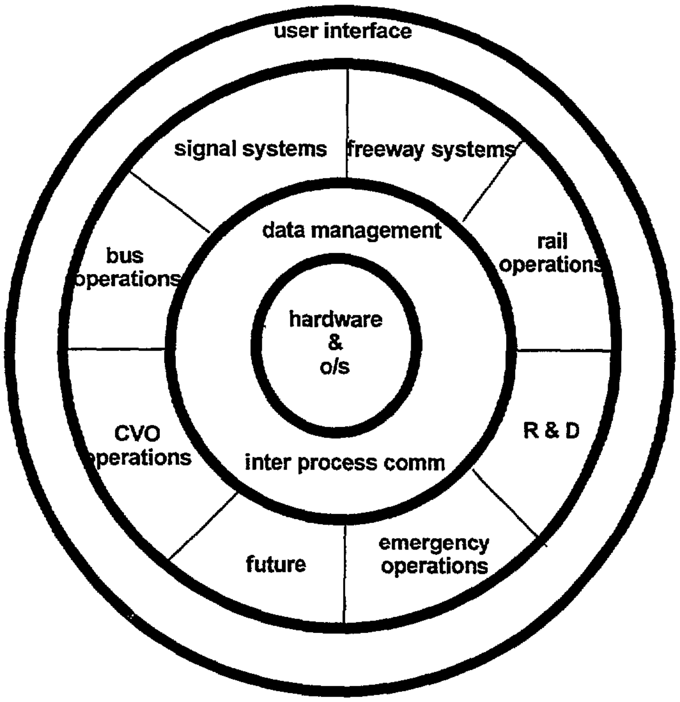

Figure 2. Conceptual Architectural Model

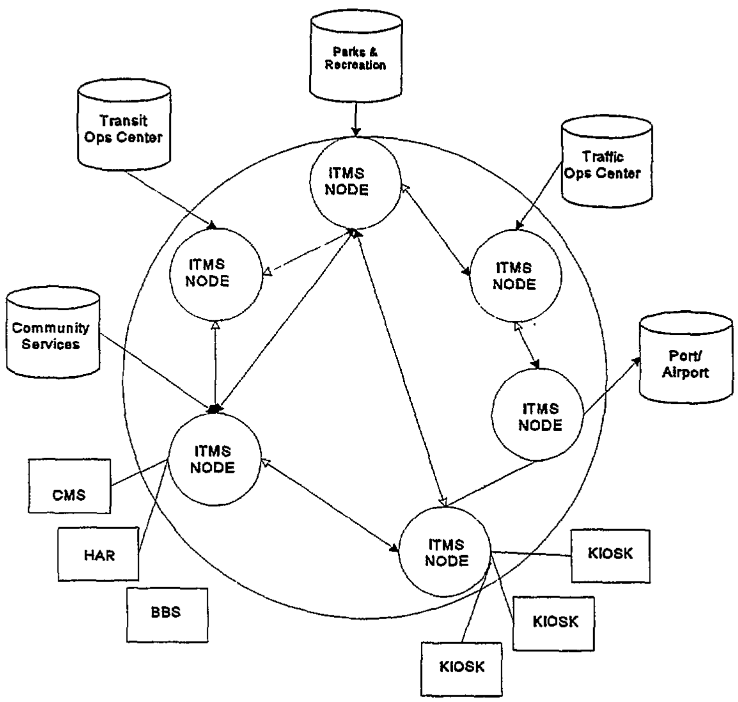

Figure 3. Technical Model (YATI System)

Figure 4 is an example of a information architecture that was developed for the same YATI system. Be warned, figure 4 at first blush may appear to be a very detailed depiction of a complex transportation management and information system in the Yosemite area. However, as detailed as the drawing is, it does not have sufficient detail to allow systems engineers to engage in detailed design. As such, the observation is made that the means by which transportation express their requirements needs to closely track the nomenclatures used by systems engineers to perform actual design work. A number of transportation agencies in the U.S. (e.g., Caltrans) have invested the time necessary to develop a method by which the needs/requirements of the traffic engineers are presented to the systems staff in a manner which directly fits the design paradigm. This approach avoids the cycle of "here is what I want, you figure out if it's implementable and let me know."

The following provides an overview of a structured, systematic process suggested for the development of an ITMS Architecture, such as those presented in figures 1, 2 and 3. The information is presented to highlight the prerequisite types of information required before an architecture, at a regional level, can be developed.

Significant Steps in Developing an Architecture

- Operations Concept
  The definition of operational concepts is the beginning of the requirements planning phase. A Joint Requirements Planning (JRP) team made up of both transportation professionals and systems engineers is encouraged to be formed in this phase. This team provides the mechanism where key agency personnel (management and users) participate in workshops where operational knowledge is collected and expressed in the form of an Operations Definition. Operations are the principles which govern and establish a need for the system. In the case of a "system of systems," emphasis needs to be placed on the type of interface to be established and the operational procedures to be followed by all participants. System inputs and outputs are identified, and as much of the system's working environment as possible. It cannot be over stated that end users are essential to discovering the subtleties of the complete transportation environment.

- Functional System Requirements
  The JRP team continues the requirements planning phase by defining the system in terms of major functions that are consistent with the operations document. It is at the functional level that an Integrated Computer Aided Software Engineering (ICASE) tool is used. ICASE is used to diagram the functional system into processes that act as a repository for the system definitions. Data flow and entity-relationship diagrams (similar to that depicted in figure 4) are used to extract system definitions and dependencies from the operations concept document. Through process refinement and decomposition, the JRP team continues to define the functional model until all the system functions are described. The Functional System Requirements document captures the system functional model by specifying the processes and data flows in requirements terminology. User interface proto-typing are often times employed by the JRP team to help clarify requirements and give an overall understanding of the functional system model.

- Baseline Performance Requirements
  Performance requirements are a distinct part of the Functional System Requirements. Capabilities identified in the system functional model often have resource critical requirements. Timing constraints and storage needs are examples of baseline performance requirements. Typically, these requirements are in terms of operational resource and not physical resource, such as: "the system shall store one year of transit data."

- Architectural Alternatives
  Within the framework of the functional system requirements (including performance) the system designers evaluated architectural alternatives. Architectural components are chosen based upon technical merits and general cost constraints. System architectures are derived by senior systems engineers to meet functional requirements. Resulting candidate architectures are evaluated by a weighted list of criteria based upon the operational objectives and organizational needs. It is strongly recommended that one criteria of the architectural evaluation process is that of open systems. Open system standards promote the use of portable, inter-operable, and vendor neutral architectures. Open standards allow the implementation of the model depicted in figure 2.

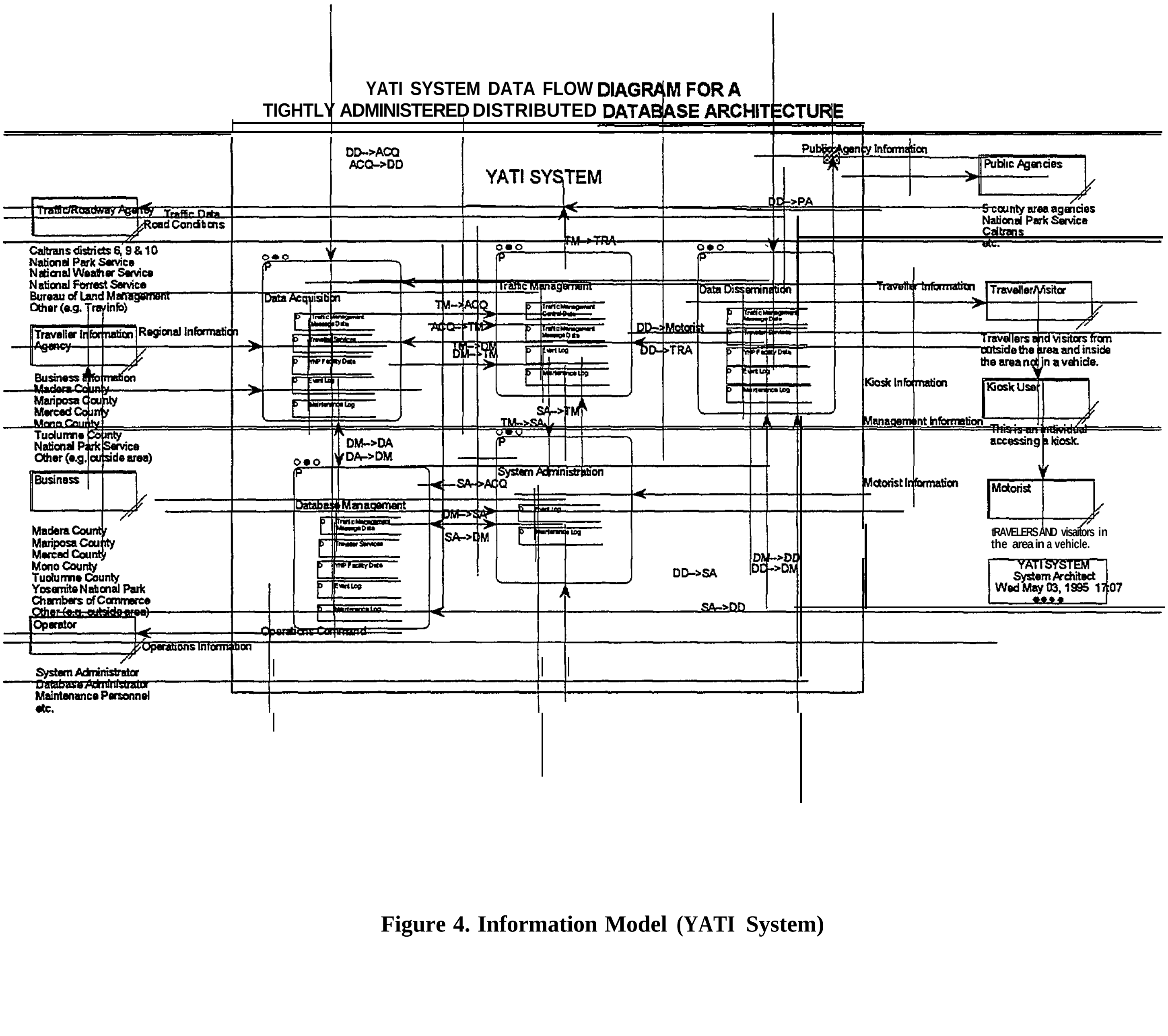

Figure 4. Information Model (YATI System)

- Design Stage
  With the functional requirements and an architectural model defined, the design team begins the user design phase using a top-down approach. ICASE and proto-typing tools are used to build upon the requirements repository from the requirements planning phase. Object-oriented Design (OOD) is a popular method to continue the design process by translating functional requirements into object classes, object relationships, and object data flows. Proto-typing and story boarding allows the user to get involved in the design process. OOD continues until the system is represented by an object model that defines the software and hardware objects. Functional requirements flow into the object design and are allocated to the software and hardware components. All requirements are traceable into the higher level documents and are verified through testing.

- Implementation Stage
  Rapid application development is accomplished by using the ICASE tool to analyze, design, code, test, and improve. Implementation becomes an evolving process constantly improving design and regenerating code. Evolving a design is only practical if the system has been cleanly engineered so that it is easy to change. ICASE keeps the repository current with the improvements and code frames are automatically updated. System modules are tested and integrated in a step-wise fashion until the system is fully integrated and ready for acceptance testing. ICASE helps to generate consistent design documentation from the data repository. Design documentation consists of object descriptions, diagrams, data dictionary, traceability matrices, and source code.

IMPORTANT CONCEPTUAL COMPONENTS FOR AN ITMS ARCHITECTURE-or-Where to get started

Recognize the Regional Differences

Transportation needs can be summarized as: efficient and safe movement of people, goods and services. On regional and national levels, the ITMS challenge is to provide an inter-connect between all transportation agencies as a common, yet distributed information entity. To consider any given architecture as the ITMS solution, may well lessen the consideration of unique agency needs that vary from region to region. It is suggested in figure 5, that the needs of an agency directly determine the operation concepts and the system performance. Operation concepts determine the functional system requirements which in turn directs the system architecture selection. The system architecture alternatives are the results of system engineers applying functional requirements against today's technologies.

Guide the ITMS Architecture Development

In order to meet the ITMS challenge for a region, the ITMS architecture must provide an effective inter-connect and merge of transportation information while at the same time remaining sensitive to the individual agency's needs. Since it is improbable that one ITMS design can satisfy all needs, it is suggested that a mechanism to guide the ITMS development toward the ITMS vision be established. For discussion purposes it is taken that the ITMS vision focuses on establishing a network of inter-operable transportation management centers that seamless"ly" share information. The solution to the ITMS challenge may well not be associated with a "one size fits all" architecture, rather to guide, influence, and encourage the ITMS vision. Figure 6 shows a two prong mechanism to guide ITMS system development. The first emphasis is in the establishment of an ITMS open standards profile with the second emphasis focusing on the ITMS recommended architectures. Note that the open ITMS standards and recommended ITMS architectures are interjected downstream of the functional system requirements into the architecture alternatives. In this manner, the system design follows the agencies functional requirements and at the same time converges on the ITMS vision.

Specifying Open Standards

X/Open has defined open systems as: "Vendor independent computing environment consisting of inter-operable products and technologies that are commonly available and that have been designed and implemented in accordance with dejure and defacto standards." A further example is taken from Caltrans' statewide Transportation Management Center Master Plan, open systems is defined as: ". . . a non proprietary system that operates on different platforms."

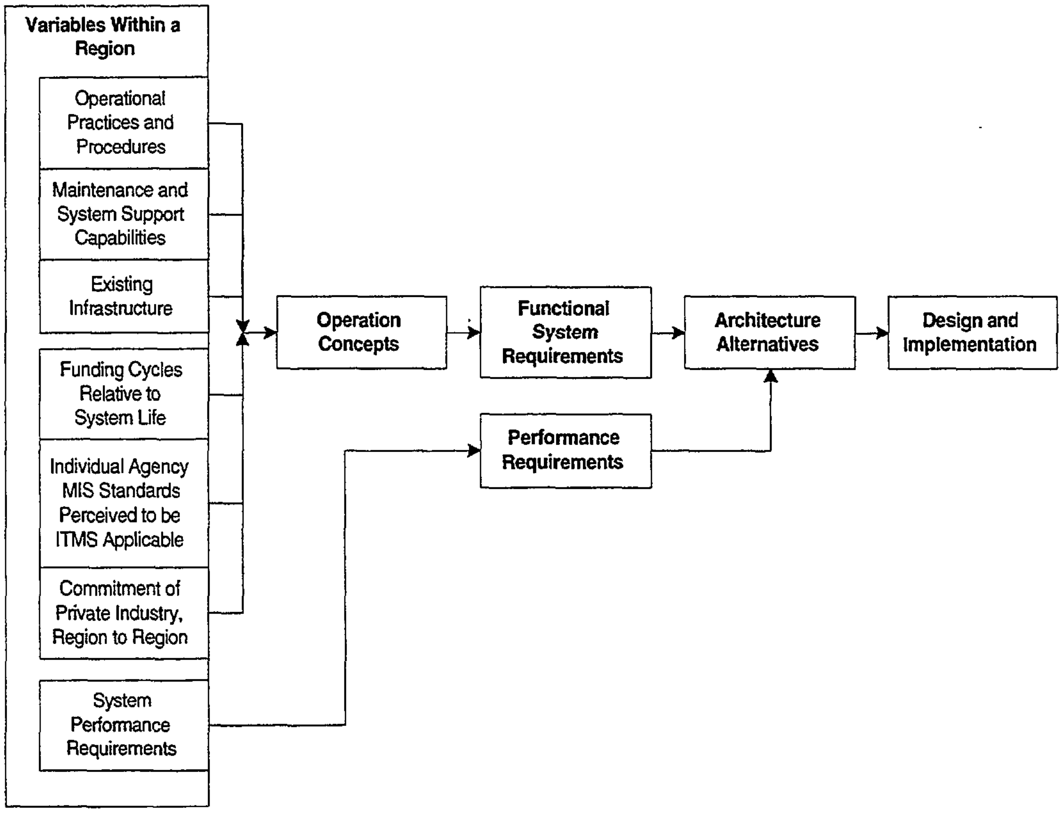

Figure 5. Region's Requirements Flow into Design

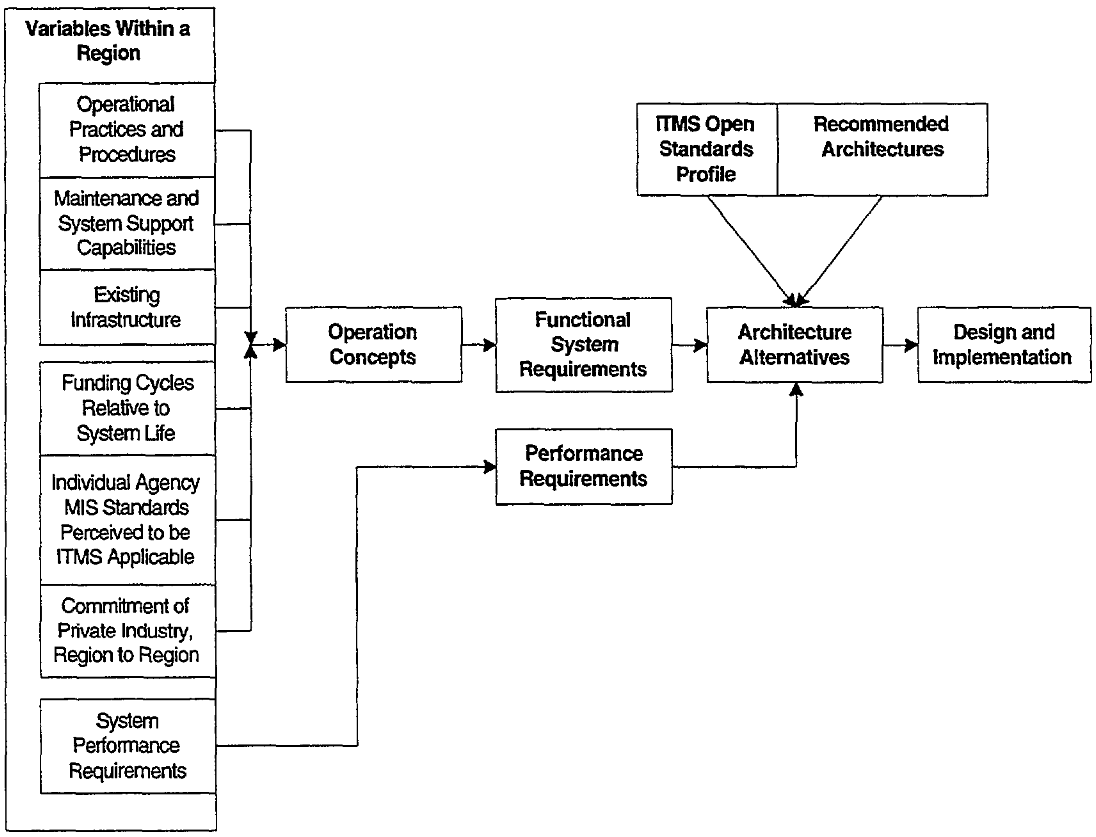

Figure 6. Mechanisms to Guide ITMS Design

Figure 2 provided an onion like model to introduce the concept of the use of open systems standards in an ITMS architecture. In defining and applying specific open system standards to support the onion model, necessitates the building of an ITMS Open Standards profile. The process of building and maintainmg an ITMS Open Standards profile requires a commitment to research and to staying abreast of industry's dynamic allocations of open standards in the areas of interest. Comprehensive knowledge of current open standards in the area of interest allows the system designer to make informed choices and assemble a profile for an Open ITS architecture. Figure 7 depicts a four step process of generating au open profile to be used in the Open ITS design for an ITMS.

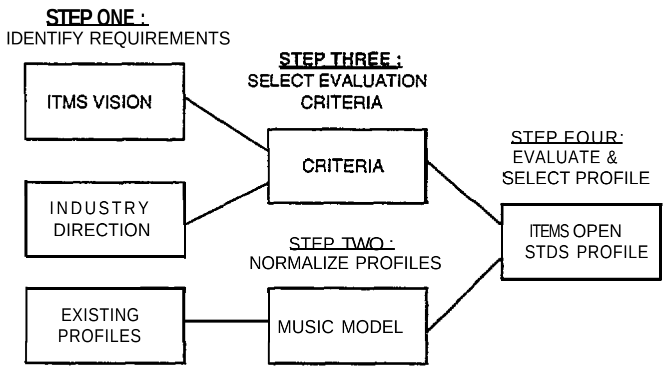

Figure 7. Selecting an Open Standards Profile

Step one is to identify requirements; sources include the ITMS vision, industry's direction, and existing profiles. Step two is the normalization of existing profiles for comparison of similar standards. Step three is the selection of evaluation criteria based upon the requirements. Step four is the evaluation and selection of an Open ITS profile.

The MUSIC Model

One accepted approach for building standard profiles is based upon a popular model for categorizing open standards called the MUSIC model. The MUSIC model was developed and used by the Central Computer and Telecommunications Agency (CCTA) of Britain for categorizing major system partitions. Figure 8 provides a graphical representation of the MUSIC model. The MUSIC acronym defines five major elements in the distributed computing environment, they are:

1. Management Services
2. User Interface
3. System Interface
4. Information and Data Services
5. Communication Services

Applying the MUSIC model to recognized industry profiles (e.g., GOSIP, TCOS, XPG) provide a way of normalizing standards for comparison and evaluation. Evaluation criteria is chosen and weighted as an indication of relative importance to the ITMS vision. In most cases Open Systems definitions of "openness" also fulfill the ITMS vision of inter-operability across modal and jurisdictional boundaries.

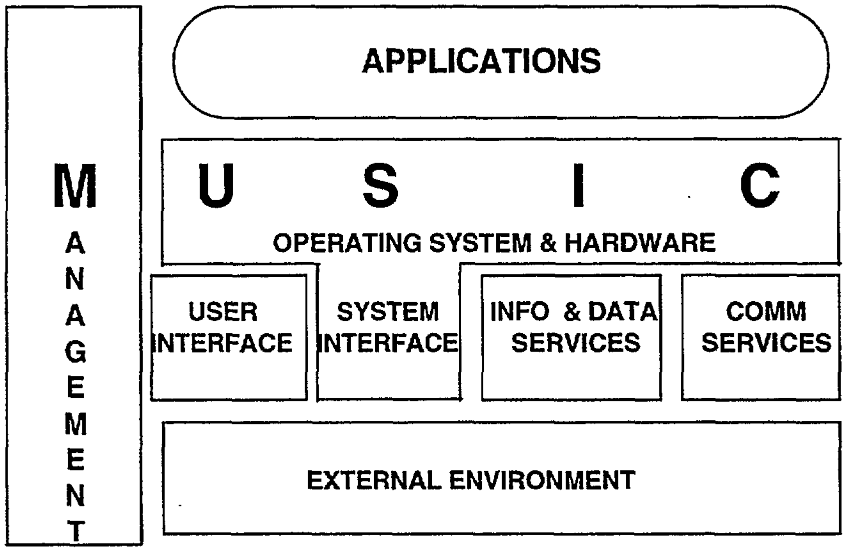

Figure 8. The MUSIC Model

CONCLUSIONS

The content of the paper provides an overview of the driving factors which influence the development of an ITMS architecture. Through the course of discussion a number of observations are made concerning the overall process by which an architecture is developed. Reference is made to the need to bring together the shared expertise of transportation and systems professionals in an integrated design team, where each express their requirements in a format and nomenclature familiar to the other. The closing sections of the paper describe the manner in which variances, region to region, will impact the final deployment of the ITMS. In bringing conclusion to the general discussion concerning the development of an ITMS architecture, consideration is now given to the process by which an ITMS is physically defined and ultimately maintained during day to day operations. Reference was made in the body of the paper to ITMS as being a "system of systems" which integrates all roads and all modes. Not referenced was the process by which participating agencies initially baseline their ITMS implementation and keep it aligned through design, implementation and operations. The use of a living, formal Configuration Management Plan (CMP) is recommended for this purpose. The CMP documents all relevant details of the ITMS ranging from open standards profiles through to detailed data dictionaries of the integrated environment. CMPs, as would be expected, tend to be very specific to the implementation which they govern. However, for the purpose of this paper the following general topics are suggested to be appropriate for inclusion in a CMP:

- Operational procedures governing the functionality of the deployed, integrated, system
- System baseline: describes the existing systems, the vision for new systems to be deployed including open standards to be observed. Acceptable migration paths for any existing proprietary systems to an open architecture will stream line integration efforts
- Configuration details: (remember figure 4) Details concerning both hardware and software components are provided
- Interface specifications: detailing the manner in which existing systems are integrated and the manner in which new systems are to be integrated
- Change Procedures: These outline the process by which participating agencies maintain and tune their individual systems while remaining aligned with the overall ITMS. A configuration management team is suggested with technical representatives from each of the participating agencies
- Minimum performance requirements for every composite piece of the entire ITMS.

APPENDIX A

Scope of the ITMS Challenge

In considering broad scope of an ITMS, several key topics surface, including:

- *What we know about: inter-modal needs, overall ITMS objectives, the probable institution implications and the rising urgency to achieve integrated transportation management.*
- *What we don't know about: specific performance (and storage) requirements, variances in operational practices and procedures region to region, variances in maintenance and system support capabilities region to region, the emerging influence of agency MIS departments on ITMS, and the commitment of private entities in supporting ITMS*
- *The meaning and interrelationship between the terms Inter-Modal and Multi-Modal*

What we know about the "Challenge"

The application of advanced technologies to our current and future transportation needs actually address a rather concise scope of mobility improvements. In fact, this scope of improvements can be examined under two basic scenarios associated with urban travel.

Urban traffic congestion can be broadly classified into two demand/capacity scenarios as recurring and non-recurring congestion. Recurring congestion occurs when demand exceeds capacity on a routine basis such as during morning and evening peak periods. Non-recurring congestion occurs when the capacity of a section of roadway is temporarily reduced due to incidents such as stalled vehicles, accidents etc. Figure 1 graphically depicts the concept of recurring congestion. The capacity of a roadway segment is constant and is represented by the straight line AB. The ordinate of the demand curve varies depending on time of day and typically exceeds capacity during peak hours. C and D represent points at which demand is equal to capacity. The shaded area between the two lines gives the total traffic delay due to recurring congestion. The time difference between the points C and D is the duration of delay.

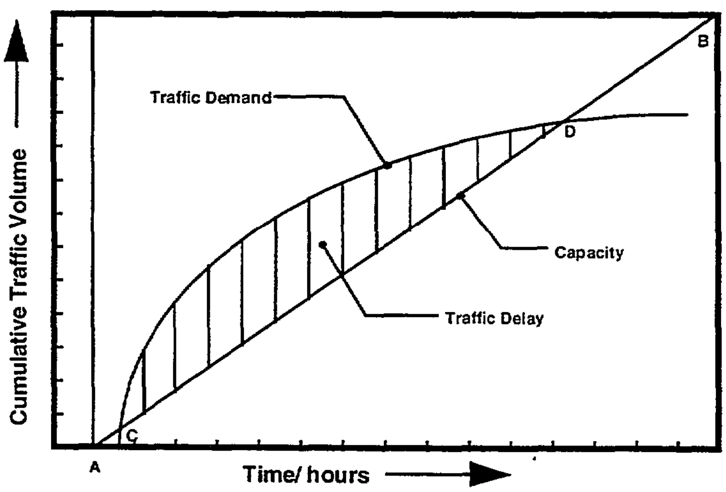

Figure 1. Recurring Congestion

Figure 2 represents the concepts of non-recurring congestion. In this scenario the demand is within the limits of capacity and the curve AC represents the demand within the capacity limits. Point A represents occurrence of an incident. At this point the demand temporarily exceeds bottleneck (effective) capacity. Point B represents incident removal and beginning of capacity restoration until it reaches point C where free flow conditions are resumed. The shaded area bounded by ABC represents total delay due to the incident and the time difference between A and C is the duration of delay due to the incident.

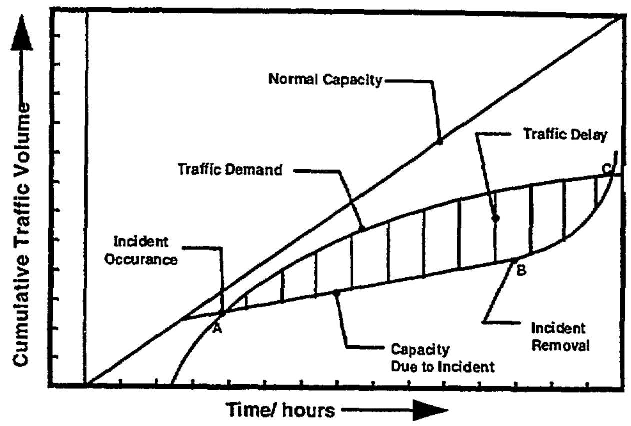

Figure 2. Non-Recurring Congestion

Concepts of ITS solutions

Several ITS elements are used as solutions to mitigate recurring and non recurring congestion. Some common ITS elements include CCTV cameras and Vehicle Detector Station (VDS) for real time monitoring and surveillance, Entry Control Systems or Ramp Metering Systems (ECS/RMS) to regulate real time demand and to mitigate congestion. CMS, HAR, TAT, Community Access Television (CATV) and Interactive Multimedia Kiosk Systems (IMKS) are used to disseminate real time traffic and traveler information and to regulate on and off-the road demand.

Two traditional methods are employed to reduce delay due to recurring congestion. These methods are regulating the demand and increasing the physical roadway capacity to meet or exceed the demand. A conceptual representation of these two methods are represented in figures 3 and 4. Figure 3 shows regulation of demand in areas where limited effective capacity due to bottlenecks are incurred. Tools employed to mitigate recurring congestion will assist in reducing the area of the delay envelope bounded by the excess demand curve and the capacity line. A common tool employed in a freeway environment within the Advanced Traffic Management System (ATMS) functional area of ITS for this purpose is ramp metering. Ramp metering regulates the rate of vehicles entering the freeway such that upstream demand is maintained at the same or lower level compared to downstream capacity. By regulating the rate of entry, breakdown in vehicle speeds and increase in delay resulting from overcrowding and turbulence can be minimized. In Figure 3, curve AC represents original demand and curve AB represents regulated demand due to ramp metering. The cross hatched area ABC represents reduction in traffic delay due to ramp metering. Other methods of reducing delay due to recurring congestion include reducing demand before the onset of congestion. These techniques include dissemination of accurate real time pre-trip traffic and traveler information to motorists so they can plan their trip to avoid congestion either on or off the road.

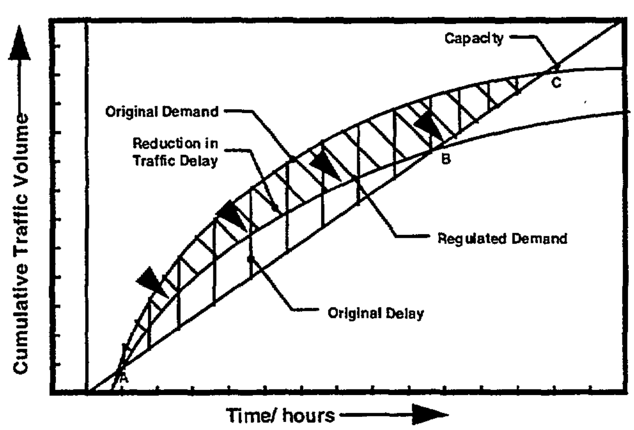

Figure 3. Solutions for Recurring Congestion - Demand Regulation

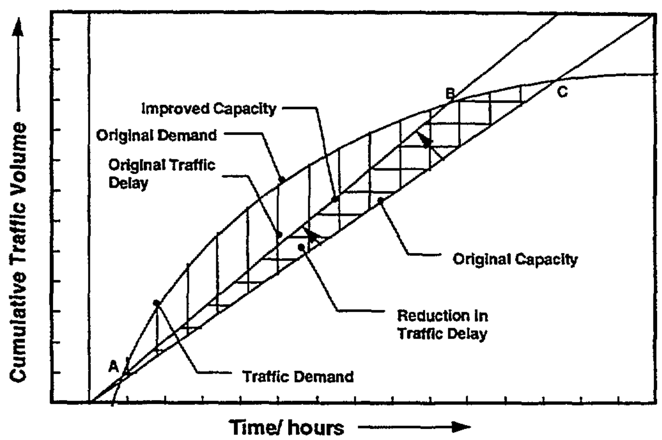

Figure 4. Solutions for Recurring Congestion - Increasing Capacity

Tools commonly employed for this purpose within the realm of the Advanced Traveler Information System (ATIS) functional area of IVHS include CMS, HAR, TAT, IMKS and personal and public bulletin boards. The ITMS extension is to optimize corridor level capacity through the integration of surface street and freeway operations as well as other modes.

Figure 4 shows the traditional solution for recurrent congestion: physical widening. Line AC represents original capacity. Line AB represents increased capacity due to widening. Cross hatched area shows delay savings due to widening. However, this option is extremely difficult to implement due to socio-economic and environmental considerations.

Figures 5 and 6 show conceptual solutions to non-recurring or incident caused congestion. Figure 5 shows reduction in effective capacity (line AB) due to an incident.

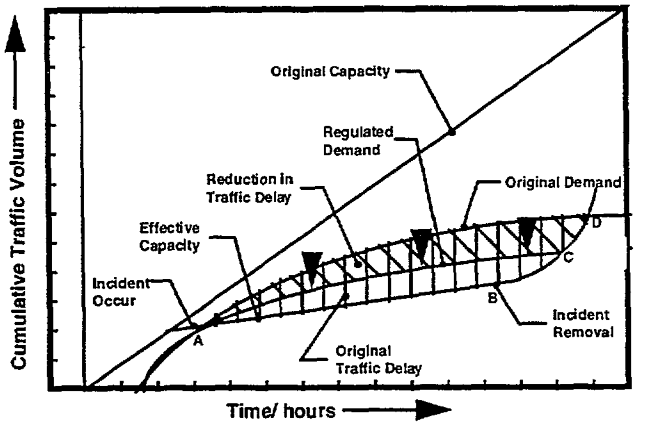

Figure 5. Solutions for Non-Recurring Congestion - Demand Regulation

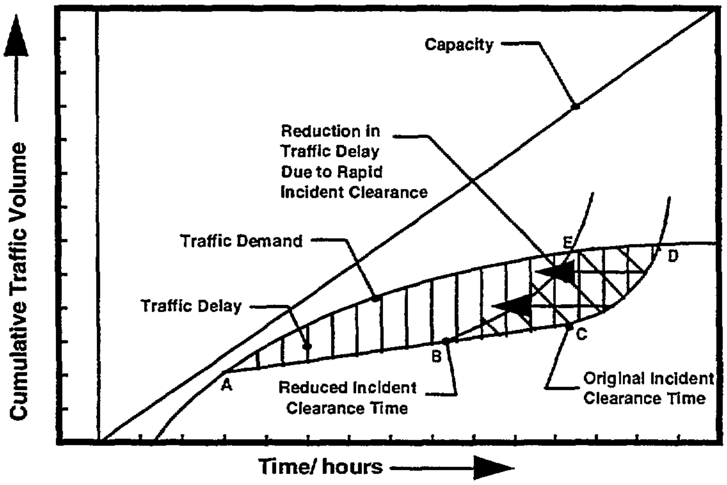

Figure 6. Solutions for Non-Recurring Congestion - Rapid Restoration in Capacity

Demand regulation at incident bottlenecks can be achieved by diverting traffic to alternative routes and by using ATIS elements. In combination with ATMS elements it is possible to achieve greater optimum capacity and safer speeds at the bottleneck locations. Cross hatched area ACD in figure 5 represents reduction in delay due to combination of ATMS and ATIS elements. The ITMS extension provides a more comprehensive tool to provide a far more complete set information concerning modal and route choices.

Figure 6 shows one of the most cost effective ways of mitigating the effects of non recurring congestion on the traffic stream: rapid incident response. Incident management consists of four main stages; identification, verification, response and removal. Rapid identification and verification of incidents using VDS and CCTV, enable the incident management team to mobilize appropriate personnel and equipment and quickly respond to the incident. Reduced time in each of the four stages of incident management results in reduced incident duration and rapid recovery of the traffic stream to normal flow. The line AC in figure 6 shows the original incident clearance time and AB represents new reduced incident clearance time. The Area bounded by EBCD represents the reduction in traffic delay due to rapid incident clearance. The ITMS deployment provides additional data sources (such as probe data from instrumented transit vehicles) to assist in the incident detection and verification process.

Further consideration of the potential for improvements noted above, reveals an underlying layer of institutional coordination and consensus which must be addressed either prior to, or in parallel with the development of an ITMS architecture. While the depth of the issues associated with these topics are left for other papers presented at the subject symposium, the dependency of the development of a useful and useable ITMS architecture on the resolution of the associated issues is noted.

Variables associated with the "Challenge"

While we are able to identify with the scope of improvements associated with an ITMS, there exists a number of associated variables which will vary region to region, and pose a significant potential to significantly impact the development of an ITMS architecture. The following summarizes some of the more critical elements:

- *Operational Practices and Procedures*
- *Maintenance and System Support Capabilities*
- *Existing Infrastructure*
- *Funding cycles relative to system life*
- *System Performance Requirements*
  - *classes of performances requirement*
  - *probable migration*
- *Individual Agency MIS standards perceived to be applicable to ITMS*
- *Commitment of private industry, region to region*

In consideration of the above, the establishment of an ITMS architecture would seem to most likely converge at the regional level. Efforts to normalize an architecture beyond the regional level would be deeply affected and confounded by the variance of the preceding from region to region. Further, an ITMS architecture will need to be sensitive to individual agencies ' desire to apply the solutions which they feel most applicable to their specific operation. However, there still exists the requirement to establish a number of interfacing standards at a National level in order for functions such as in vehicle communications, to be functions. With these requirements, and in consideration of the rather obvious need for systems in a common region to be interoperable, the need to establish regional configuration management plans is critical. This concept is pursued further in the closing section of this paper.

Inter-Modal and Multi-Modal

The terms Multi-Modal and Inter-Modal are becoming a common part of the ITS vernacular. However, while the use if the terms is on the rise, a clear definition of the meaning, interpretation, interrelationship and implications of the terms is no yet well defined. For the work currently underway in Southern California where the State shall deliver four separate Intennodal Transportation Management Centers, over the next 6 to 24 months, the need has existed for some time to establish an understanding of these terms and the manner in which an ITMS supports the concepts defined. The following summarizes the definitions currently being applied:

- *Inter-Modal is considered to focus on the real time activities associated with individuals mode selection and use. Further, inter-modal also refers to the agencies attempts to affect mode selection on a day to day basis and in real time*
- *Multi-Modal is considered to address the planning and design process to establish multi-modal transportation networks. Additionally, the efforts of the agencies to affect travel behavioral patterns over the long term are likewise associated with the term multi-modal.*

With these general definitions in place, a number further observations have been posed in Southern California. The following highlights relevant observations which pertain to the subject paper:

- ***A firm and recognizable Inter-Modal operations concept should be the foundation on which the planning and design of a Multi-Modal network is based***

- ***An ITMS, in merging data from all modes, can act as a catalyst to bridge multi-modalplanning and design with realistic inter-modal operations concepts.***

OPERATIONS AND MAINTENANCE OF INTEGRATED TRANSPORTATION MANAGEMENT SYSTEMS

Edwin Rowe, Gardner-Rowe Systems

INTRODUCTION

So far at this Symposium, we have for the most part heard the good news-Integrated Transportation Management Systems are going to provide public agencies the means to better manage traffic and provide useful services to the traveling public. We have heard how a combination of advanced technologies involving networked computers, complex software, fiber optic and microwave communication systems, detectorlzation of all of our highways, CCTV, changeable message signs, highway advisory radio, and much more will make this possible. The bad news is that most of this new high-tech equipment and software will be the responsibility of state and local agencies to operate and maintain. If we're not careful, this wonderful dream could turn into our worst nightmare as inadequate resources are overwhelmed by the demands of operations and maintenance. This looming problem has been referred to as the potential "Achilles' Heel of ITS" [1].

Fortunately, operations and maintenance of ITS projects was recognized as a major problem facing public agencies several years ago. As a result, there have been surveys, studies, white papers, seminars, and work shops devoted to this issue. In this paper, I will briefly summarize these past efforts devoted to a better understanding of the problem and then discuss the primary issues that public agencies need to address in order to adequately operate and maintain Integrated Transportation Management Systems (ITMS). These issues are organized into four broad categories: implementation, expertise, institutional, and funding.

BACKGROUND

Federal Government Actions

In 1990, the FHWA Office of Program Review conducted a survey of 24 representative traffic control systems deployed by state and local agencies. The report on this survey found that 21 of the systems inspected did not meet minimum standards of performance due to inadequate operations and maintenance [2]. Needless to say, these findings raised concerns regarding the plans for a national ITS program involving deployment of advanced technologies, when state and local agencies were for the most part not up to operating and maintaining much less complex technologies.

The FHWA immediately established an internal Task Force to investigate what actions they might take to improve the situation. The FHWA Task Force report was submitted in March of 1991 [3]. The FHWA also established an Expert Panel composed of representatives from state and local agencies, a consulting firm, and an university. The Expert Panel report was completed in March of 1992, and contained 34 recommendations for consideration by the FHWA, state and local agencies [4]. Both the Task Force and the Expert Panel reports identified the need to expand the eligibility of Federal gas tax funds for purposes of operations and maintenance of traffic control systems.

The FHWA incorporated the highest priority recommendations of the Expert Panel report into an Action Plan which was released in November, 1992 [5]. The Action Plan also noted nine other FHWA projects that would contribute to the improved operations and maintenance of traffic control systems.

The General Accounting Office performed its own review of the problems that are preventing state and local agencies from realizing the benefits from traffic control systems. The GAO submitted a report on their study to the House of Representatives Committee on Energy and Commerce in March of 1994 [6]. The GAO report essentially reinforced the conclusions of the earlier reports and recommended several specific actions for the FHWA.

ITE Actions

As a result of the FHWA Action Plan, the ITE contracted with the FHWA to perform certain tasks as part of the ITE/FHWA Joint Project on Urban Traffic Engineering. This project included mail and phone surveys of state and local agencies, and focus groups. Three reports based on these surveys are nearing completion [7, 8, 9].

In October of 1994 a National Conference on Operating and Maintaining Traffic Control Systems was held in Dallas, Texas. To stimulate discussion at the Conference, nine white papers on various aspects of operating and maintaining Traffic Control Systems were prepared [10]. A final report on the Conference was also prepared and distributed [11]. Following the Conference, a seminar was held sponsored by the ITE Educational Foundation which included additional papers and background information on the subject of Operations and Maintenance [12].

Another related task contracted to the ITE was the establishment of a national clearing house for the distribution of information on traffic control systems. The clearing house includes a toll free hot line and an electronic bulletin board.

Recognizing the importance of operations and maintenance of traffic control systems, the ITE's ITS Council has established a task force committee to investigate this subject area.

IMPLEMENTATION ISSUES

System Design

In the past, more often than not, an analysis of operations and maintenance requirements has been left until the near the end of the design phase of the project. As a result, design trade-off analyses of various options, performed earlier in the project, often have not adequately considered the long term "life-cycle" operations and maintenance cost and staffing consequences. Furthermore, personnel who will be responsible for operations and maintenance tasks are not always included in design reviews. The adverse consequences of these past practices will be even more severe with regard to implementing future ITMS projects that utilize advanced technologies. The following suggestions are made to better insure that the final design of an ITMS fully reflects operations and maintenance requirements and limitations:

- Consider operations and maintenance requirements *from the beginning* of the system design phase.
- Include personnel responsible for operations and maintenance in design reviews throughout the system design phase.
- Trade-off analyses of hardware and software design options should include the long term life-cycle effect on operations/maintenance cost and staffing. It should be assumed that most state and local agencies will face continuing budget and staffing constraints; therefore, design decisions should generally attempt to minimize the impact of operations and maintenance life-cycle costs even though first costs will probably be higher as a result.

Design Standards

Adoption of uniform design standards for hardware, software, communications, and installation that are consistent throughout the multi-jurisdictional area covered by the ITMS will serve to reduce the complexity of the integrated system, simplify hardware interfaces, and reduce long term operations and maintenance problems.

The use of the National Traffic Control/ITS Communications Protocol (NTCIP) Standard currently under development will provide for communication between traffic management centers and traffic signal controllers initially and other types of field traffic devices as the protocol is expanded.

In the case of software development for ITMS projects, an Open Systems Environment (OSE) and extensive use of commercial off-the-shelf (COTS) products should be specified whenever possible. An Open Systems Environment is a complete environment for the development and implementation of computing systems based on a publicly available set of interfaces, protocols, services, and supporting documents. The basic objectives of an OSE is to provide portability, scalability, and interoperability. Adoption of an OSE should reduce development costs as well as long term maintenance and training costs.

System Procurement

State and local procurement processes that worked acceptably for building highways or low-tech signal control systems are usually not suitable for ITMS projects. The implementation of ITMS projects poses new challenges involving not only the integration of numerous advanced technologies, but also multi-jurisdictional compatibility. There has been a general recognition of the need to update procurement practices of public agencies to meet the specific requirements of advanced technology systems.

The most recent discussion of this issue can be found in the National ITS Program Plan [13]. This report recommends studies aimed at streamlining Federal regulatory requirements regarding projects and identifying revisions in State procurement guidelines. Areas of procurement reform suggested are:

- Protection of intellectual property rights in order to foster innovation
- Cost accounting/cost certification and auditing requirements
- Procurement compliance costs
- Organizational conflict of interest limitations regarding selection of the same firm to both design and build ITS applications.

Procurement limitations requiring strict adherence to acceptance of low-bid system components can result in poor reliability, incompatible equipment from different sources performing the same functions, and multi-jurisdictional system integration problems. Higher operations and maintenance costs are usually the result. Where advanced technologies and/or multi-jurisdictional ITMS are involved, the flexibility to deviate from low-bid regulations needs to be considered.

Construction Inspection and Acceptance Testing

A rigorous construction inspection program for all field installed equipment is a good investment for identifying and correcting system installation deficiencies before they become maintenance problems. This is particularly true of communication cabling and loop detectors.

A formal system acceptance testing plan for ITMS implementation projects should be a requirement. As in the case of construction inspection, system testing will yield a significant payoff relative to reducing future maintenance problems. The system testing plan should utilize a building block approach for software, hardware, and system integration. For example, field hardware components would be tested prior to installation, at the subsystem level after integration with communications and software, and at the full system level in conjunction with other system elements,

Hardware and Software Documentation

Extensive documentation of installed ITMS hardware and software can serve to mitigate the time required to diagnose and correct the inevitable operations and maintenance problems encountered after acceptance of the system. Unfortunately, it has been the experience with many systems that these products are not produced until the end of the project when remaining funds are usually running low. This is another task where an additional up-front investment can result in significant long term benefits.

STAFFINGAND TRAINING ISSUES

Staffing

In the past, state and local agencies usually have not fully anticipated the resources that were required to operate and maintain traffic control systems. The ITMS that are currently in the planning and development stage will present even greater demands on the responsible agencies. These demands involve the addition of new staff and the creation of appropriate position descriptions for the types of personnel needed to operate the advanced technologies comprising ITMS. A greater emphasis on electronic engineering, computer science, and digital technician skills will be required to maintain micro-electronic circuits, communication networks composed of fiber optics and wireless components, closed circuit television, changeable message signs, and computer systems. Engineers with strong traffic operations backgrounds will be needed to staff the operations centers.

No specific national guidelines currently exist for determining the staffing requirements for operating and maintaining ITMS. This is no doubt due to the large number of variables involved and the differences between each ITMS project. Staffing requirements can and should be developed well before the installation of the ITMS. These requirements should be based to a large extent on maintaining minimum levels of system performance. For example, a loop failure would be only tolerated for a specified period of time after identification. The number of staff required to meet such minimum performance levels would be expected to vary from system to system depending on the type of equipment deployed, the amount of equipment, the geographic extent of the system, the hours and days of operation, the functions performed, and estimates of the mean time to failure of various system components.

Frequent turnover of operations and maintenance staff can adversely affect ITMS performance. The ability of the public agency to pay competitive wage rates and provide career promotional paths for the positions required should be evaluated by management. The expectation of achieving these personnel objectives within a sometimes resistant Civil Service System may not be realistic. If personnel adjustments appear necessary that can not be made in the time required, then consideration should be given to out-sourcing the required functions to private contractors.

Training

An on-going training program should be developed prior to the turn-on date of ITMS. This training program should focus on three phases-system installation, the period just prior to system turn-on, and the long term period of system operation.

Ideally, the core staff should have been hired and basic training performed during system installation. This is an excellent time for “over-the-shoulder” training.

The second phase of training consists of the prime contractor and sub-contractors providing agency staff with class room and “hands-on” training in all essential operations and maintenance functions prior to system turn-on.

After system turn-on, the training program should take advantage of the large number of training opportunities available through University short courses, the National Highway Institute courses, the Local Transportation Assistance Program (LTAP), U.S. DOT Transportation Centers and Advanced Institutes Programs, and ITE workshops and seminars. The objective of such training should be to move beyond performance of the basic function which can be largely learned from the prime contractor’s training course and operations and maintenance manuals. An ITMS is a very powerful traffic management tool that can achieve the expected high performance standards only with an adequately trained and motivated staff.

Contracting Operations and Maintenance

Maintenance contracts for certain specialized equipment such as computers is the usual case. General system maintenance and system operation tasks for the last generation of traffic control systems, however, have been normally performed by public agency staff. With the advent of large scale multi-jurisdictional ITMS, the advantages of contracting additional maintenance and even control center operations functions are greater due to economies of scale. The multi-jurisdictional ITMS can allow for pooling of funds from several public agencies and the single administration of larger contracts. This relieves the smaller agencies of the burden of maintaining the advanced technologies implemented by ITMS. Also, the larger agencies with prime responsibilities for the ITMS operation and maintenance can focus more on administration of the activity rather than developing and retaining highly specialized staff.

The INFORM system in Long Island, New York, is a good example of this type of long term contracting arrangement for operations and maintenance of an ITMS.

INSTITUTIONAL ISSUES

Operations and Maintenance Agreements

The process for implementing an ITMS can take many forms. Inter-agency cooperation is essential for the success of these endeavors. Agreements regarding operations and maintenance responsibilities and levels of effort will be required and should be established prior to actual construction of the ITMS during the preliminary design stage. Allocation of funds for ITMS project improvements in participating jurisdictions should be made contingent on such agreements.

Operations Across Jurisdictional Boundaries

During the course of the design of the ITMS, but prior to system turn-on, it will be necessary to establish policies and procedures for the coordination of inter-jurisdictional operations. These procedures must cover such issues as incident management, congestion management, diversion of traffic from freeways to city streets, messages placed on CMS, ramp metering and closure policies, and coordination of traffic signals at jurisdictional boundaries.

The convening of a team of representatives from all participating jurisdictions to develop a consensus on these policy and procedure issues will be required. In addition to formal agreements on the operational policies, many of the procedures may be incorporated into the operations software developed for the ITMS. For example in the case of the Los Angeles Smart Corridor Project, the inter-jurisdictional operational responses to specific traffic conditions and events have been directly input into an on-line expert system.

Joint Maintenance of Equipment

An ITMS will often be composed of a few large and a number of smaller local agencies. The smaller local agencies will often not have the in-house technical capabilities to adequately maintain the ITMS equipment under their jurisdiction. In these cases, consideration should be given to joint jurisdictional maintenance agreements in which one of the larger agencies provides maintenance for the less capable agencies. However, this will open the larger agency to additional tort liability exposure which may not be acceptable. In those cases, the use of private contracting for maintenance should be considered. As noted previously, one contract could be issued covering the maintenance requirements for several agencies.

Technology Transfer

The organizational structure created for an ITMS also opens up new opportunities for technology transfer among the cooperating state and local agencies. Local agencies are often unaware of the results of research and development efforts sponsored by the FHWA despite an active technology transfer program. Also, participants in ITMS projects may conduct their own research into the effectiveness of various operational strategies and develop new improved maintenance procedures. The closer public agency relationships fostered by the ITMS projects should facilitate the more frequent sharing of this valuable technical information among all participating agencies.

Internal Reorganization

The traditional organization of transportation departments often works against the appropriate allocation of maintenance resources to ITMS. These systems are typically designed in one division, operated in another division, and maintained in yet another division. Since ITMS is a relatively new product, maintenance supervisors are not always aware of the criticality of certain types of routine maintenance and also may view this new responsibility as a lower priority than more familiar functions.

In order to better insure that the maintenance of ITMS is given the necessary priority it deserves, it may be necessary to reorganize the transportation department. A matrix type organization in which the manager in charge of ITMS operations is also given some authority over the maintenance of ITMS equipment would serve to mitigate the existing internal organizational problems.

FUNDING ISSUES

Funding is a Maior Long Term Problem

The establishment of an adequate and dependable long term funding source for ITMS projects is probably the major challenge facing state and local agencies. This problem has historical roots in the manner by which highway projects including those involving traffic control have been funded. Funds for design and implementation come from one budgetary source (often Federal gas tax) and funds for operations and maintenance come from another source (often the General Fund in the case of local agencies). This separation in funding sources has frequently resulted in ample funds for project implementation and inadequate funds for critical operations and maintenance functions. This, in turn, has resulted in progressive degradation in system performance.

Over the past 15 years, the financial condition of most local governments has noticeably worsened, with tax payer revolts such as Proposition 13 in California reducing General Fund revenues for cities and counties to the point that little is left over for anything but the most vital services. State transportation agencies are also experiencing much tighter budgets which often result in reducing operations and maintenance activities. Furthermore, the state and local transportation agencies are usually at a severe competitive disadvantage relative to the many competing programs which can muster bus loads of constituents to pack legislative chambers and can more effectively utilize lobbyists for their interests.

It cannot be reasonably expected that this situation will improve anytime soon. Consequently, the expectation of adequate operations and maintenance funds for our ITMS projects is not favorable unless new sources of funding are found.

ISTEA

Certain provisions of ISTEA go part way towards a solution to this problem of funding operations and maintenance. Two years of startup costs are allowed for projects funded under the National Highway System. Under provisions of the Surface Transportation Program, ITMS operating costs can be funded indefinitely. The Congestion Mitigation and Air Quality Program (CMAQ) allows for two years of operating costs.

These provisions in ISTEA are certainly a move in the right direction compared to previous restrictions on the use of Federal gas tax funds for operations and maintenance purposes. Every effort should be made, however, to revise this legislation to allow complete flexibility by state and local agencies in the allocation of Federal gas tax funds to operations and maintenance of ITMS. It is noteworthy that Europe and Japan do not generally place the types of restrictions on funding operations and maintenance that we do in the United States.

State and local agencies should also be more proactive in their use of currently available ISTEA funds for operations of ITMS. One of the best current examples of such use of ISTEA is New York City which has budgeted $7.4 million annually from the Surface Transportation Program for the operation of their ITMS [14].

State and local agencies cannot rely entirely on the Federal gas tax for operations and maintenance of ITMS projects.

At a minimum, matching funds will be required. To the extent that any restrictions on the use of state gas tax funds for operations and maintenance of ITMS by local agencies exist, they should be removed. Furthermore, it would be in the interest of insuring long term continuity of operations and maintenance to allocate a set amount of annual state gas tax funds for this purpose. The formula allocation for operations and maintenance would be best made at the time of approval of implementation funds for ITMS projects.

CONCLUSIONS

Progress has been made in the last five years in raising the level of consciousness of the ITS community to the importance of giving greater emphasis to the operations and maintenance functions in order to achieve the expectations of improved mobility and safety.

A number of relatively recent studies, reports, and services provide useful information for developing more effective operations and maintenance programs.

Greater attention does need to be devoted during the design process to decisions on equipment, software, and installation procedures that will minimize long term *life-cycle* operations and maintenance costs, even though first costs may be higher.

The use of existing *open standards* for communications and software should be used whenever possible.

Antiquated procurement procedures need to be revised in order to allow for deviations from low cost bid requirements and other restrictions that prevent the implementation of systems that will minimize *life-cycle* operations and maintenance costs.

State and local agencies will be hard pressed to provide staff with the necessary skills to operate and maintain ITMS on an uninterrupted long term basis and should consider private contracting of various functions.

Training of state and local agency staff should start nearer the beginning of the implementation phase rather than at the end which is often the case.

ITMS programs should require agreement by all participating agencies on a minimum level of operations and maintenance support prior to allocation of funds,

The implementation of ITMS opens up new opportunities for inter-agency cooperation on operations and maintenance within regional areas.

Given the expectation that the financial conditions of state and local agencies will not improve inthe foreseeable future, the historical restrictions on the use of Federal gas tax capital funding sources for operations and maintenance activities needs to be reconsidered. ISTEA and/or its successor should be revised to allow for full flexibility in the allocation of funds for ITMS operations and maintenance purposes.

State gas tax funds should also be made fully available to local agencies for operations and maintenance of ITMS, and where possible allocated for this purpose on a long term basis upon approval of the project.

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